

CHAPTER 8

HYDRAULIC AND PNEUMATIC POWER SYSTEMS

AIRCRAFT HYDRAULIC SYSTEMS

The word hydraulics is based on the Greek word for water, and originally meant the study of the physical behavior of water at rest and in motion. Today the meaning has been expanded to include the physical behavior of all liquids, including hydraulic fluid.

Hydraulic systems are not new to aviation. Early aircraft had hydraulic brake systems. As aircraft became more sophisticated newer systems with hydraulic power were developed.

Although some aircraft manufacturers make greater use of hydraulic systems than others, the hydraulic system of the average modern aircraft performs many functions. Among the units commonly operated by hydraulic systems are landing gear, wing flaps, speed and wheel brakes, and flight control surfaces.

Hydraulic systems have many advantages as a power source for operating various aircraft units. Hydraulic systems combine the advantages of light weight, ease of installation, simplification of inspection, and minimum maintenance requirements. Hydraulic operations are also almost 100% efficient, with only a negligible loss due to fluid friction.

All hydraulic systems are essentially the same, regardless of their function. Regardless of application, each hydraulic system has a minimum number of components, and some type of hydraulic fluid.

HYDRAULIC FLUID

Hydraulic system liquids are used primarily to transmit and distribute forces to various units to be actuated. Liquids are able to do this because they are almost incompressible. Pascal's Law states that pressure applied to any part of a confined liquid is transmitted with undiminished intensity to every other part. Thus, if a number of passages exist in a system, pressure can be distributed through all of them by means of the liquid.

Manufacturers of hydraulic devices usually specify the type of liquid best suited for use with their equipment, in view of the working conditions, the

service required, temperatures expected inside and outside the systems, pressures the liquid must withstand, the possibilities of corrosion, and other conditions that must be considered.

If incompressibility and fluidity were the only qualities required, any liquid not too thick might be used in a hydraulic system. But a satisfactory liquid for a particular installation must possess a number of other properties. Some of the properties and characteristics that must be considered when selecting a satisfactory liquid for a particular system are discussed in the following paragraphs.

Viscosity

One of the most important properties of any hydraulic fluid is its viscosity. Viscosity is internal resistance to flow. A liquid such as gasoline flows easily (has a low viscosity) while a liquid such as tar flows slowly (has a high viscosity). Viscosity increases with temperature decreases.

A satisfactory liquid for a given hydraulic system must have enough body to give a good seal at pumps, valves, and pistons; but it must not be so thick that it offers resistance to flow, leading to power loss and higher operating temperatures. These factors will add to the load and to excessive wear of parts. A fluid that is too thin will also lead to rapid wear of moving parts, or of parts which have heavy loads.

The viscosity of a liquid is measured with a viscosimeter or viscometer. There are several types, but the instrument most often used by engineers in the U.S. is the Saybolt universal viscosimeter (figure 8-1). This instrument measures the number of seconds it takes for a fixed quantity of liquid (60 cc. (cubic centimeters)) to flow through a small orifice of standard length and diameter at a specific temperature. This time of flow is taken in seconds, and the viscosity reading is expressed as SSU (seconds, Saybolt universal). For example, a certain liquid might have a viscosity of 80 SSU at 130° F.

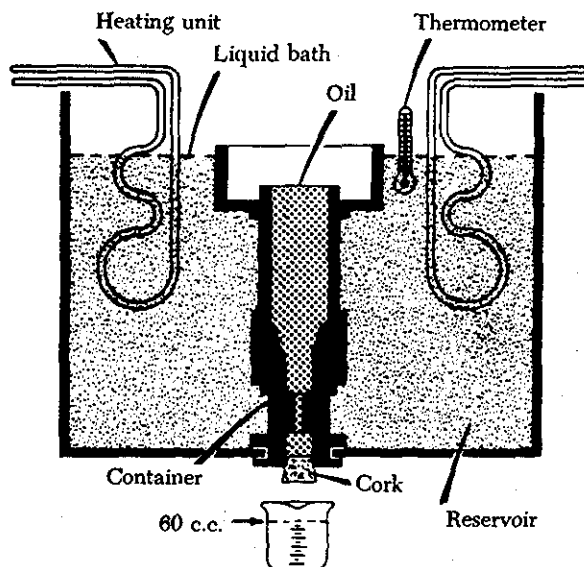


FIGURE 8-1. Saybolt viscosimeter.

Chemical Stability

Chemical stability is another property which is exceedingly important in selecting a hydraulic liquid. It is the liquid's ability to resist oxidation and deterioration for long periods. All liquids tend to undergo unfavorable chemical changes under severe operating conditions. This is the case, for example, when a system operates for a considerable period of time at high temperatures.

Excessive temperatures have a great effect on the life of a liquid. It should be noted that the temperature of the liquid in the reservoir of an operating hydraulic system does not always represent a true state of operating conditions. Localized hot spots occur on bearings, gear teeth, or at the point where liquid under pressure is forced through a small orifice. Continuous passage of a liquid through these points may produce local temperatures high enough to carbonize or sludge the liquid, yet the liquid in the reservoir may not indicate an excessively high temperature. Liquids with a high viscosity have a greater resistance to heat than light or low viscosity liquids which have been derived from the same source. The average hydraulic liquid has a low viscosity. Fortunately, there is a wide choice of liquids available for use within the viscosity range required of hydraulic liquids.

Liquids may break down if exposed to air, water, salt, or other impurities, especially if they are in constant motion or subject to heat. Some metals,

such as zinc, lead, brass, and copper, have an undesirable chemical reaction on certain liquids.

These chemical processes result in the formation of sludge, gums, and carbon or other deposits which clog openings, cause valves and pistons to stick or leak, and give poor lubrication to moving parts. As soon as small amounts of sludge or other deposits are formed, the rate of formation generally increases more rapidly. As they are formed, certain changes in the physical and chemical properties of the liquid take place. The liquid usually becomes darker in color, higher in viscosity, and acids are formed.

Flash Point

Flash point is the temperature at which a liquid gives off vapor in sufficient quantity to ignite momentarily or flash when a flame is applied. A high flash point is desirable for hydraulic liquids because it indicates good resistance to combustion and a low degree of evaporation at normal temperatures.

Fire Point

Fire point is the temperature at which a substance gives off vapor in sufficient quantity to ignite and continue to burn when exposed to a spark or flame. Like flash point, a high fire point is required of desirable hydraulic liquids.

TYPES OF HYDRAULIC FLUIDS

To assure proper system operation and to avoid damage to non-metallic components of the hydraulic system, the correct fluid must be used.

When adding fluid to a system, use the type specified in the aircraft manufacturer's maintenance manual or on the instruction plate affixed to the reservoir or unit being serviced.

There are three types of hydraulic fluids currently being used in civil aircraft.

Vegetable Base Hydraulic Fluid

Vegetable base hydraulic fluid (MIL-H-7644) is composed essentially of castor oil and alcohol. It has a pungent alcoholic odor and is generally dyed blue. Although it has a similar composition to automotive type hydraulic fluid, it is not interchangeable. This fluid is used primarily in older type aircraft. Natural rubber seals are used with vegetable base hydraulic fluid. If it is contaminated with petroleum base or phosphate ester base fluids, the seals will swell, break down and block the system. This type fluid is flammable.

Mineral Base Hydraulic Fluid

Mineral base hydraulic fluid (MIL-H-5606) is processed from petroleum. It has an odor similar to penetrating oil and is dyed red. Synthetic rubber seals are used with petroleum base fluids. Do not mix with vegetable base or phosphate ester base hydraulic fluids. This type fluid is flammable

PHOSPHATE ESTER BASE FLUIDS

Non-petroleum base hydraulic fluids were introduced in 1948 to provide a fire-resistant hydraulic fluid for use in high performance piston engines and turboprop aircraft.

These fluids were fire-resistance tested by being sprayed through a welding torch flame (6000°). There was no burning, but only occasional flashes of fire. These and other tests proved non-petroleum base fluids (Skydrol®) would not support combustion. Even though they might flash at exceedingly high temperatures, Skydrol® fluids could not spread a fire because burning was localized at the source of heat. Once the heat source was removed or the fluid flowed away from the source, no further flashing or burning occurred.

Several types of phosphate ester base (Skydrol®) hydraulic fluids have been discontinued. Currently used in aircraft are Skydrol® 500B—a clear purple liquid having good low temperature operating characteristics and low corrosive side effects; and, Skydrol® LD—a clear purple low weight fluid formulated for use in large and jumbo jet transport aircraft where weight is a prime factor.

Intermixing of Fluids

Due to the difference in composition, vegetable base, petroleum base and phosphate ester fluids *will not mix*. Neither are the seals for any one fluid useable with or tolerant of any of the other fluids. Should an aircraft hydraulic system be serviced with the wrong type fluid, immediately drain and flush the system and maintain the seals according to the manufacturer's specifications.

Compatibility With Aircraft Materials

Aircraft hydraulic systems designed around Skydrol® fluids should be virtually trouble-free if properly serviced. Skydrol® does not appreciably affect common aircraft metals—aluminum, silver, zinc, magnesium, cadmium, iron, stainless steel, bronze, chromium, and others—as long as the fluids are kept free of contamination.

Due to the phosphate ester base of Skydrol® fluids, thermoplastic resins, including vinyl compositions, nitrocellulose lacquers, oil base paints, linoleum and asphalt may be softened chemically by Skydrol® fluids. However, this chemical action

usually requires longer than just momentary exposure; and spills that are wiped up with soap and water do not harm most of these materials.

Paints which are Skydrol® resistant include epoxies and polyurethanes. Today polyurethanes are the standard of the aircraft industry because of their ability to keep a bright, shiny finish for long periods of time and for the ease with which they can be removed.

Skydrol® is a registered trademark of Monsanto Company. Skydrol® fluid is compatible with natural fibers and with a number of synthetics, including nylon and polyester, which are used extensively in most aircraft.

Petroleum oil hydraulic system seals of neoprene or Buna-N are not compatible with Skydrol® and must be replaced with seals of butyl rubber or ethylene-propylene elastomers. These seals are readily available from any suppliers.

Health and Handling

Skydrol® fluid does not present any particular health hazard in its recommended use. Skydrol® fluid has a very low order of toxicity when taken orally or applied to the skin in liquid form. It causes pain on contact with eye tissue, but animal studies and human experience indicate Skydrol® fluid causes no permanent damage. First aid treatment for eye contact includes flushing the eyes immediately with large volumes of water and the application of any anesthetic eye solution. If pain persists, the individual should be referred to a physician.

In mist or fog form, Skydrol® is quite irritating to nasal or respiratory passages and generally produces coughing and sneezing. Such irritation does not persist following cessation of exposure.

Silicone ointments, rubber gloves, and careful washing procedures should be utilized to avoid excessive repeated contact with Skydrol® in order to avoid solvent effect on skin.

Hydraulic Fluid Contamination

Experience has shown that trouble in a hydraulic system is inevitable whenever the liquid is allowed to become contaminated. The nature of the trouble, whether a simple malfunction or the complete destruction of a component, depends to some extent on the type of contaminant.

Two general contaminants are:

- (1) Abrasives, including such particles as core sand, weld spatter, machining chips, and rust.

- (2) Nonabrasives, including those resulting from oil oxidation, and soft particles worn or shredded from seals and other organic components.

Contamination Check

Whenever it is suspected that a hydraulic system has become contaminated, or the system has been operated at temperatures in excess of the specified maximum, a check of the system should be made. The filters in most hydraulic systems are designed to remove most foreign particles that are visible to the naked eye. Hydraulic liquid which appears clean to the naked eye may be contaminated to the point that it is unfit for use.

Thus, visual inspection of the hydraulic liquid does not determine the total amount of contamination in the system. Large particles of impurities in

the hydraulic system are indications that one or more components in the system are being subjected to excessive wear. Isolating the defective component requires a systematic process of elimination. Fluid returned to the reservoir may contain impurities from any part of the system. To determine which component is defective, liquid samples should be taken from the reservoir and various other locations in the system.

Samples should be taken in accordance with the applicable manufacturer's instructions for a particular hydraulic system. Some hydraulic systems are equipped with permanently installed bleed valves for taking liquid samples, whereas on other systems, lines must be disconnected to provide a place to take a sample. In either case, while the fluid is being taken, a small amount of pressure should be applied to the system. This ensures that the liquid will flow out of the sampling point and thus prevent

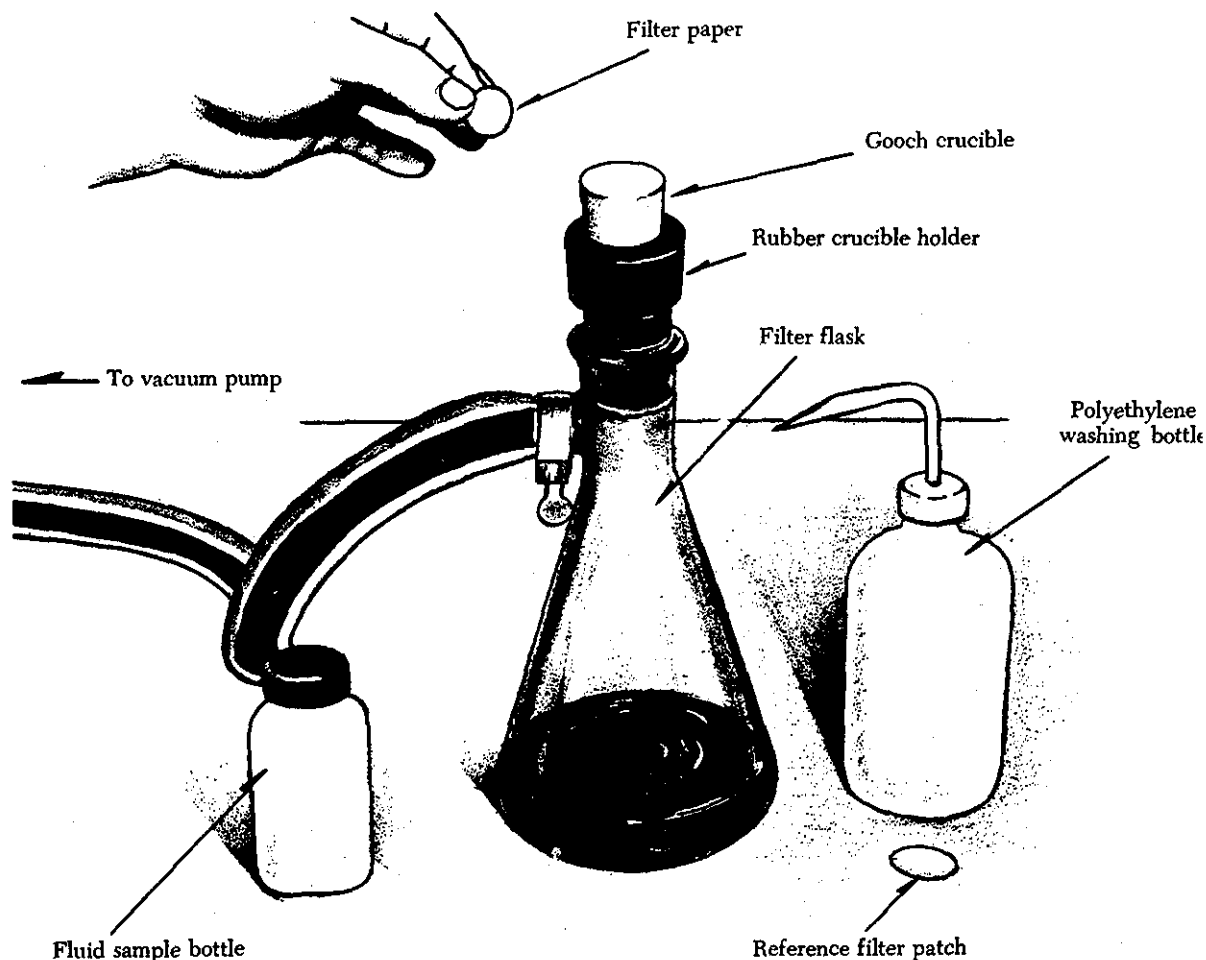


FIGURE 8-2. Contamination test kit.

dirt from entering the hydraulic system. Some contamination test kits have hypodermic syringes for taking samples.

Various test procedures are used to determine the contamination level in hydraulic liquids. The filter patch test provides a reasonable idea of the condition of the fluid. This test consists basically of filtration of a sample of hydraulic system liquid through a special filter paper. This filter paper darkens in degree in relation to the amount of contamination present in the sample, and is compared to a series of standardized filter disks which, by degree of darkening, indicate the various contamination levels. The equipment provided with one type of contamination test kit is illustrated in figure 8-2.

When using this type of contamination test kit, the liquid samples should be poured through the filter paper, and the test filter paper should be compared with the test patches supplied with the test kit. More expensive test kits have a microscope for making this comparison.

To check liquid for decomposition, pour new hydraulic liquid into a sample bottle of the same size and color as the bottle containing the liquid to be checked. Visually compare the color of the two bottles. Liquid which is decomposed will be darker in color.

At the same time the contamination check is made, it may be necessary to make a chemical test. This test consists of a viscosity check, a moisture check, and a flash point check. However, since special equipment is required for these checks, the liquid samples must be sent to a laboratory, where a technician will perform the test.

Contamination Control

Filters provide adequate control of the contamination problem during all normal hydraulic system operations. Control of the size and amount of contamination entering the system from any other source is the responsibility of the people who service and maintain the equipment. Therefore, precautions should be taken to minimize contamination during maintenance, repair, and service operations. Should the system become contaminated, the filter element should be removed and cleaned or replaced.

As an aid in controlling contamination, the following maintenance and servicing procedures should be followed at all times:

- (1) Maintain all tools and the work area (workbenches and test equipment) in a clean, dirt-free condition.
- (2) A suitable container should always be provided to receive the hydraulic liquid that is spilled during component removal or disassembly procedures.
- (3) Before disconnecting hydraulic lines or fittings, clean the affected area with dry cleaning solvent.
- (4) All hydraulic lines and fittings should be capped or plugged immediately after disconnecting.
- (5) Before assembly of any hydraulic components, wash all parts in an approved dry cleaning solvent.
- (6) After cleaning the parts in the dry cleaning solution, dry the parts thoroughly and lubricate them with the recommended preservative or hydraulic liquid before assembly. Use only clean, lint-free cloths to wipe or dry the component parts.
- (7) All seals and gaskets should be replaced during the re-assembly procedure. Use only those seals and gaskets recommended by the manufacturer.
- (8) All parts should be connected with care to avoid stripping metal slivers from threaded areas. All fittings and lines should be installed and torqued in accordance with applicable technical instructions.
- (9) All hydraulic servicing equipment should be kept clean and in good operating condition.

FILTERS

A filter is a screening or straining device used to clean the hydraulic fluid, thus preventing foreign particles and contaminating substances from remaining in the system. If such objectionable material is not removed, it may cause the entire hydraulic system of the aircraft to fail through the breakdown or malfunctioning of a single unit of the system.

The hydraulic fluid holds in suspension tiny particles of metal that are deposited during the normal wear of selector valves, pumps, and other system components. Such minute particles of metal may injure the units and parts through which they pass if they are not removed by a filter. Since tolerances within the hydraulic system components are

quite small, it is apparent that the reliability and efficiency of the entire system depends upon adequate filtering.

Filters may be located within the reservoir, in the pressure line, in the return line, or in any other location where the designer of the system decides that they are needed to safeguard the hydraulic system against impurities.

There are many models and styles of filters. Their position in the aircraft and design requirements determine their shape and size.

Most filters used in modern aircraft are of the inline type. The inline filter assembly is comprised of three basic units: head assembly, bowl, and element. The head assembly is that part which is secured to the aircraft structure and connecting lines. Within the head there is a bypass valve which routes the hydraulic fluid directly from the inlet to the outlet port if the filter element becomes clogged with foreign matter. The bowl is the housing which holds the element to the filter head and is that part which is removed when element removal is required.

The element may be either a micronic, porous metal, or magnetic type. The micronic element is made of a specially treated paper and is normally thrown away when removed. The porous metal and magnetic filter elements are designed to be cleaned by various methods and replaced in the system.

Micronic Type Filters

A typical micronic type filter is shown in figure 8-3. This filter utilizes an element made of specially treated paper which is formed in vertical convolutions (wrinkles). An internal spring holds the elements in shape.

The micronic element is designed to prevent the passage of solids greater than 10 microns (0.000394 inch) in size (figure 8-4). In the event that the filter element becomes clogged, the spring loaded relief valve in the filter head will bypass the fluid after a differential pressure of 50 p.s.i. has been built up.

Hydraulic fluid enters the filter through the inlet port in the filter body and flows around the element inside the bowl. Filtering takes place as the fluid passes through the element into the hollow core, leaving the foreign material on the outside of the element.

Maintenance of Filters

Maintenance of filters is relatively easy. It mainly involves cleaning the filter and element or cleaning the filter and replacing the element.

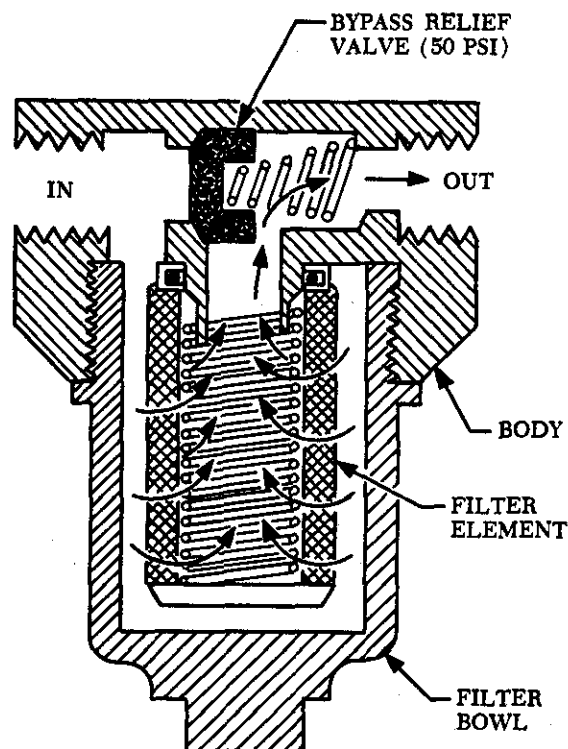


FIGURE 8-3. Hydraulic filter, micronic type.

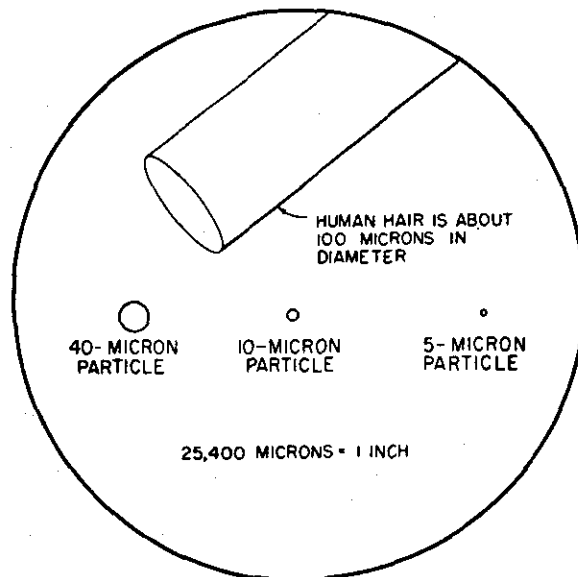


FIGURE 8-4. Enlargement of small particles.

Filters using the micronic-type element should have the element replaced periodically according to applicable instructions. Since reservoir filters are of the micronic type, they must also be periodically changed or cleaned. Filters using other than

the micron-type element, cleaning the filter and element is usually all that is necessary. However, the element should be inspected very closely to insure that it is completely undamaged. The methods and materials used in cleaning all filters are too numerous to mention. Consult the manufacturer's instructions for this information.

Some hydraulic filters have been equipped with an indicator pin that will visually indicate a clogged element. When this pin protrudes from the filter housing, the element should be removed and cleaned; also, the fluid downstream of the filter should be checked for contamination and flushed if required. All remaining filters should be checked for contamination and cleaned (if required) to determine the cause of contamination.

BASIC HYDRAULIC SYSTEM

Regardless of its function and design, every hydraulic system has a minimum number of basic components in addition to a means through which the fluid is transmitted.

Hand Pump System

Figure 8-5 shows a basic hydraulic system. The first of the basic components, the reservoir, stores the supply of hydraulic fluid for operation of the system. It replenishes the system fluid when needed, provides room for thermal expansion, and in some systems provides a means for bleeding air from the system.

A pump is necessary to create a flow of fluid. The pump shown in figure 8-5 is hand operated; however, aircraft systems are, in most instances equipped with engine-driven or electric motor-driven pumps.

The selector valve is used to direct the flow of fluid. These valves are normally actuated by solenoids or manually operated, either directly or indirectly through use of mechanical linkage. An actuating cylinder converts fluid pressure into useful work by linear or reciprocating mechanical motion, whereas a motor converts fluid pressure into useful work by rotary mechanical motion.

The flow of hydraulic fluid can be traced from the reservoir through the pump to the selector valve in figure 8-5. With the selector valve in the position shown, the hydraulic fluid flows through the selector valve to the right-hand end of the actuating cylinder. Fluid pressure then forces the piston to the left, and at the same time the fluid which is on the left side of the piston (figure 8-5) is forced out, up through the selector valve, and back to the reservoir through the return line.

When the selector valve is moved to the opposite position, the fluid from the pump flows to the left

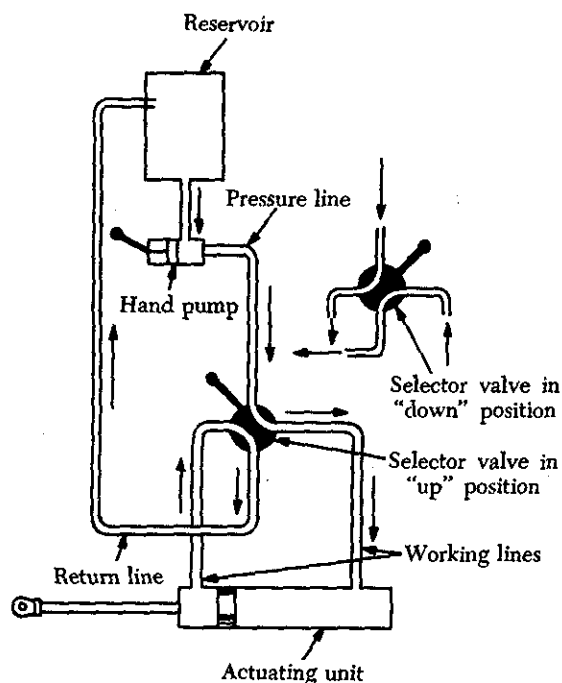


FIGURE 8-5. Basic hydraulic system with hand pump.

side of the actuating cylinder, thus reversing the process. Movement of the piston can be stopped at any time by moving the selector valve to neutral. In this position, all four ports are closed and pressure is trapped in both working lines.

Power Driven Pump System

Figure 8-6 shows a basic system with the addition of a power-driven pump and filter, pressure regulator, accumulator, pressure gage, relief valve, and two check valves. The function of each of these components is described in the following paragraphs.

The filter removes foreign particles from the hydraulic fluid, preventing dust, grit, or other undesirable matter from entering the system.

The pressure regulator unloads or relieves the power-driven pump when the desired pressure in the system is reached. Thus, it is often referred to as an unloading valve. When one of the actuating units is being operated and pressure in the line between the pump and selector valve builds up to the desired point, a valve in the pressure regulator automatically opens and fluid is bypassed back to the reservoir. This bypass line is shown in figure 8-6 leading from the pressure regulator to the return line.

Many hydraulic systems do not use a pressure regulator, but have other means of unloading the

pump and maintaining the desired pressure in the system. These methods are described in this chapter.

The accumulator (figure 8-6) serves a twofold purpose: (1) It acts as a cushion or shock absorber by maintaining an even pressure in the system, and (2) It stores enough fluid under pressure to provide for emergency operation of certain actuating units. Accumulators are designed with a compressed air chamber which is separated from the fluid by a flexible diaphragm or movable piston.

The pressure gage (figure 8-6) indicates the amount of hydraulic pressure in the system.

The relief valve is a safety valve installed in the system to bypass fluid through the valve back to the reservoir in case excessive pressure is built up in the system.

The check valves allow the flow of fluid in one direction only. Check valves are installed at various points in the lines of all aircraft hydraulic systems. In figure 8-4, one check valve prevents power-pump pressure from entering the hand-pump line; the other prevents hand-pump pressure from being directed to the accumulator.

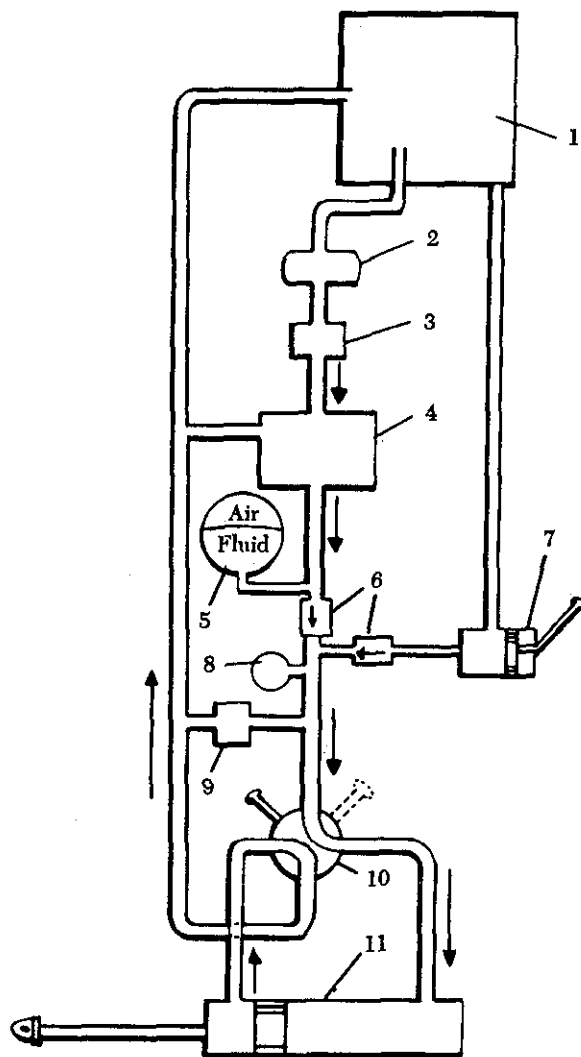
The units of a typical hydraulic system used most commonly are discussed in detail in the following paragraphs. Not all models or types are included, but examples of typical components are used in all cases.

RESERVOIRS

There is a tendency to envision a reservoir as an individual component; however, this is not always true. There are two types of reservoirs and they are:

- (1) In-Line—this type has its own housing, is complete within itself, and is connected with other components in a system by tubing or hose.
- (2) Integral—this type has no housing of its own but is merely a space set aside within some major component to hold a supply of operational fluid. A familiar example of this type is the reserve fluid space found within most automobile brake master cylinders.

In an in-line reservoir (figure 8-7), a space is provided in the reservoir, above the normal level of the fluid, for fluid expansion and the escape of entrapped air. Reservoirs are never intentionally filled to the top with fluid. Most reservoirs are designed so the rim of the filler neck is somewhat below the top of the reservoir to prevent over filling during servicing. Most reservoirs are equipped with



- | | |
|-----------------------|--------------------|
| 1. Reservoir | 7. Hand pump |
| 2. Power pump | 8. Pressure gage |
| 3. Filter | 9. Relief valve |
| 4. Pressure regulator | 10. Selector valve |
| 5. Accumulator | 11. Actuating unit |
| 6. Check valves | |

FIGURE 8-6. Basic hydraulic system with power pump and other hydraulic components.

a dipstick or a glass sight gage by which fluid level can be conveniently and accurately checked.

Reservoirs are either vented to the atmosphere or closed to the atmosphere and pressurized. In vented reservoirs, atmospheric pressure and gravity are the forces which cause fluid to flow from the reservoir

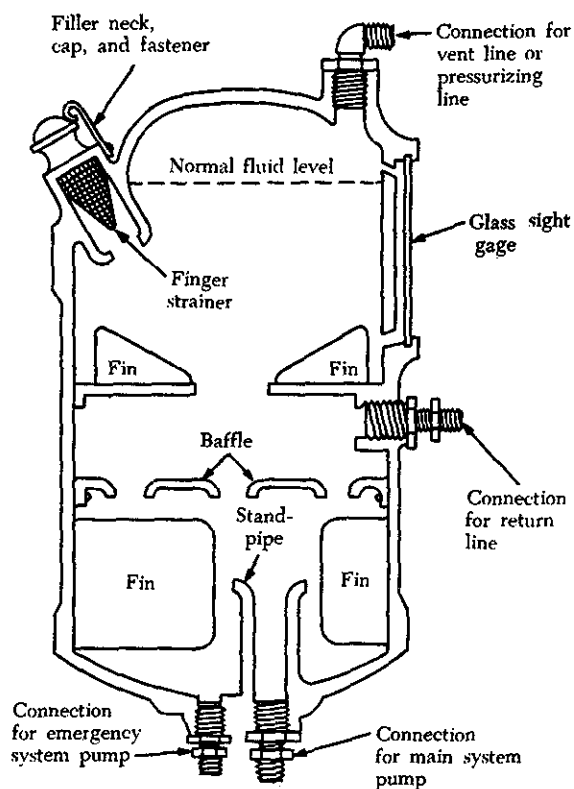


FIGURE 8-7. Reservoir, "in-line".

into the pump intake. On many aircraft, atmospheric pressure is the principal force causing fluid to flow to the pump intake. However, for some aircraft, atmospheric pressure becomes too low to supply the pump with adequate fluid, and the reservoirs must be pressurized.

There are several methods of pressurizing a reservoir. Some systems use air pressure directly from the aircraft cabin pressurization system; or from the engine compressor in the case of turbine-powered aircraft. Another method used is an aspirator or venturi-tee. In other systems an additional hydraulic pump is installed in the supply line at the reservoir outlet to supply fluid under pressure to the main hydraulic pump.

Pressurizing with air is accomplished by forcing air into the reservoir above the level of the fluid. In most cases, the initial source of the air pressure is the aircraft engine from which it is bled. Usually, air coming directly from the engine is at a pressure of approximately 100 p.s.i. This pressure is reduced to between 5 and 15 p.s.i., depending upon the type

of hydraulic system, by using an air pressure regulator.

Reservoirs that are pressurized with hydraulic fluid (figure 8-8) are constructed somewhat differently from reservoirs pressurized with air. A flexible, coated-fabric bag, called a "bellowfram" or diaphragm, is attached to the reservoir head. The bag hangs inside a metal barrel to form a fluid container. The bottom of the diaphragm rests on a large piston. Attached to the large piston is an indicator rod. The other end of the indicator rod is machined to form a small piston which is exposed to fluid pressure from the hydraulic pump. This pressure forces the small piston upward, causing the larger piston to move upward, thus producing a reservoir pressure of approximately 30 to 32 p.s.i. in normal operation. If the internal pressure should exceed 46 p.s.i., the reservoir relief valve will open allowing fluid to escape through the drilled head of the valve retainer. This type of reservoir must be completely filled with hydraulic fluid and have all the air bled from it.

Reservoir Components

Baffles and/or fins are incorporated in most reservoirs to keep the fluid within the reservoir from

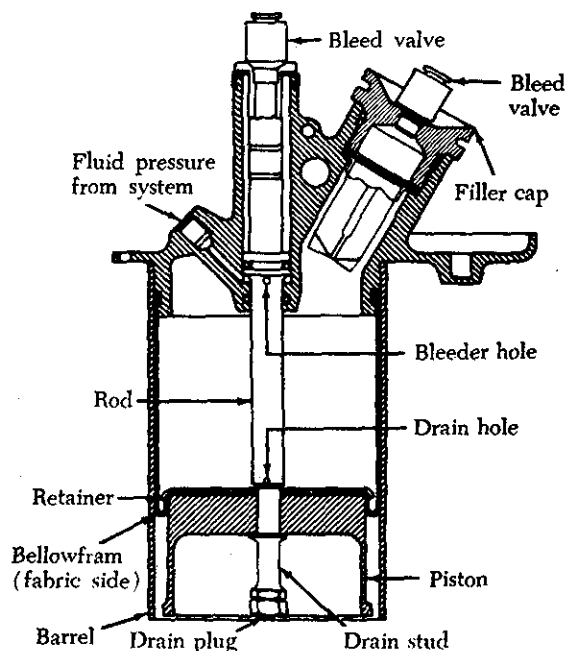


FIGURE 8-8. Hydraulic reservoir pressurized with hydraulic fluid.

having random movement such as vortexing (swirling) and surging. These conditions can cause fluid to foam and air to enter the pump along with the fluid.

Many reservoirs incorporate strainers in the filler neck to prevent the entry of foreign matter during servicing. These strainers are made of fine mesh screening and are usually referred to as finger strainers because of their shape. Finger strainers should never be removed or punctured as a means of speeding up the pouring of fluid into the reservoir.

Some reservoirs incorporate filter elements. They may be used either to filter air before it enters the reservoir or to filter fluid before it leaves the reservoir. A vent filter element, when used, is located in the upper part of the reservoir, above the fluid level. A fluid filter element, when used, is located at or near the bottom of the reservoir. Fluid, as it returns to the reservoir, surrounds the filter element and flows through the wall of the element. This leaves any fluid contaminant on the outside of the filter element.

Reservoirs with filter elements incorporate a bypass valve normally held closed by a spring. The bypass valve ensures that the pump will not be starved of fluid if the filter element becomes clogged. A clogged filter causes a partial vacuum to develop and the spring-loaded bypass valve opens. The filter element most commonly used in reservoirs is the micronic type. These filter elements are made of treated cellulose formed into accordion-like pleats. The pleats expose the fluid to the maximum amount of filter surface within a given amount of space. These micronic elements are capable of removing small particles of contamination.

Some aircraft have emergency hydraulic systems that take over if main systems fail. In many such systems, the pumps of both systems obtain fluid from a single reservoir. Under such circumstances a supply of fluid for the emergency pump is ensured by drawing the hydraulic fluid from the bottom of the reservoir. The main system draws its fluid through a standpipe located at a higher level. With this arrangement, adequate fluid is left for operation of the emergency system should the main system's fluid supply become depleted.

Double Action Hand Pumps

The double-action hydraulic hand pump is used in some older aircraft and in a few newer systems

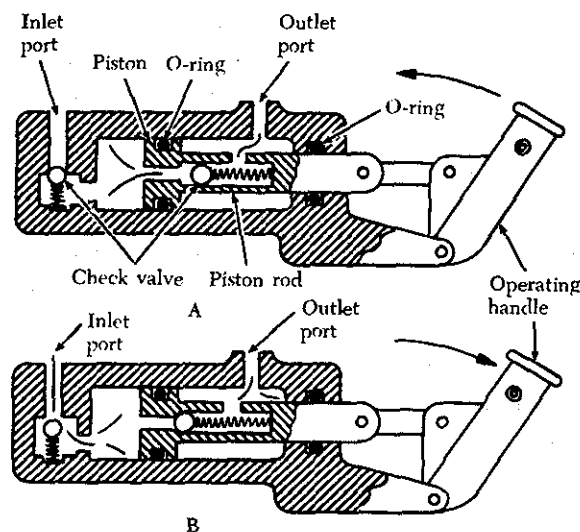


FIGURE 8-9. Double-action hand pump.

as a backup unit. Double-action hand pumps produce fluid flow and pressure on each stroke of the handle.

The double-action hand pump (figure 8-9) consists essentially of a housing which has a cylinder bore and two ports, a piston, two spring-loaded check valves, and an operating handle. An O-ring on the piston seals against leakage between the two chambers of the piston cylinder bore. An O-ring in a groove in the end of the pump housing seals against leakage between the piston rod and housing.

Power-Driven Pumps

Many of the power-driven hydraulic pumps of current aircraft are of variable-delivery, compensator-controlled type. There are some constant-delivery pumps in use. Principles of operation are the same for both types of pumps. Because of its relative simplicity and ease of understanding, the constant-delivery pump is used to describe the principles of operation of power-driven pumps.

Constant-Delivery Pump

A constant-delivery pump, regardless of pump r.p.m., forces a fixed or unvarying quantity of fluid through the outlet port during each revolution of the pump. Constant-delivery pumps are sometimes called constant-volume or fixed-delivery pumps. They deliver a fixed quantity of fluid per revolution, regardless of the pressure demands. Since the constant-delivery pump provides a fixed quantity of fluid during each revolution of the pump, the quantity of fluid delivered per minute will depend upon

pump r.p.m. When a constant-delivery pump is used in a hydraulic system in which the pressure must be kept at a constant value, a pressure regulator is required.

Variable-Delivery Pump

A variable-delivery pump has a fluid output that is varied to meet the pressure demands of the system by varying its fluid output. The pump output is changed automatically by a pump compensator within the pump.

Pumping Mechanisms

Various types of pumping mechanisms are used in hydraulic pumps, such as gears, gerotors, vanes, and pistons. The piston-type mechanism is commonly used in power-driven pumps because of its durability and capability to develop high pressure. In 3,000 p.s.i. hydraulic systems, piston-type pumps are nearly always used.

Gear Type Pump

A gear-type power pump (figure 8-10) consists of two meshed gears that revolve in a housing. The driving gear is driven by the aircraft engine or some other power unit. The driven gear meshes with, and is driven by, the driving gear. Clearance between the teeth as they mesh, and between the teeth and the housing, is very small. The inlet port of the pump is connected to the reservoir, and the outlet port is connected to the pressure line. When the driving gear turns in a counterclockwise direction, as shown in figure 8-10, it turns the driven gear in a clockwise direction. As the gear teeth pass the inlet port, fluid is trapped between the gear teeth and the housing, and is then carried around the housing to the outlet port.

Gerotor Type Pump

A gerotor-type power pump (figure 8-11) consists essentially of a housing containing an eccentric-shaped stationary liner, an internal gear rotor having five wide teeth of short height, a spur driving gear having four narrow teeth, and a pump cover which contains two crescent-shaped openings. One opening extends into an inlet port, and the other extends into an outlet port. The pump cover as shown in figure 8-11 has its mating face turned up to clearly show the crescent-shaped openings. When the cover is turned over and properly installed on the pump housing, it will have its inlet port on the left and the outlet port on the right.

During the operation of the pump, the gears turn

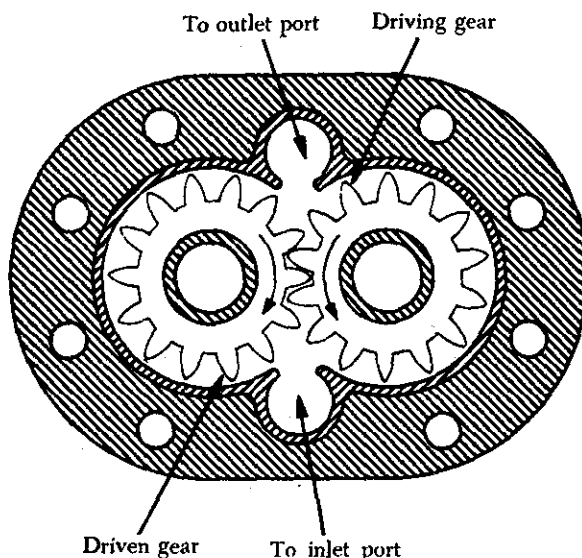


FIGURE 8-10. Gear-type power pump.

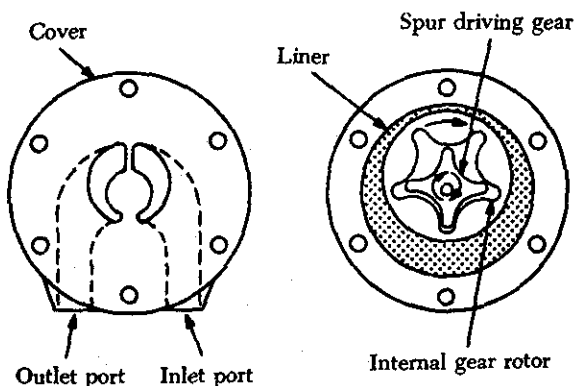


FIGURE 8-11. Gerotor-type power pump.

clockwise. As the pockets on the left side of the pump move from a lowermost position toward a topmost position, the pockets increase in size (figure 8-11) resulting in the production of a partial vacuum within these pockets. As the pockets open at the inlet port, fluid is drawn into them. As these same pockets (now full of fluid) rotate over to the right side of the pump, moving from the topmost position toward the lowermost position, they decrease in size. This results in the fluid being expelled from the pockets through the outlet port.

Vane Type Pump

The vane-type power pump (figure 8-12) consists of a housing containing four vanes (blades), a hollow steel rotor with slots for the vanes, and a cou-

pling to turn the rotor. The rotor is positioned off center within the sleeve. The vanes, which are mounted in the slots in the rotor, together with the rotor, divide the bore of the sleeve into four sections. As the rotor turns, each section, in turn, passes one point where its volume is at a minimum, and another point where its volume is at a maximum. The volume gradually increases from minimum to maximum during one-half of a revolution, and gradually decreases from maximum to minimum during the second half of the revolution. As the volume of a given section is increasing, that section is connected to the pump inlet port through a slot in the sleeve. Since a partial vacuum is produced by the increase in volume of the section, fluid is drawn into the section through the pump inlet port and the slot in the sleeve. As the rotor turns through the second half of the revolution, and the volume of the given section is decreasing, fluid is displaced out of the section, through the slot in the sleeve, through the outlet port, and out of the pump.

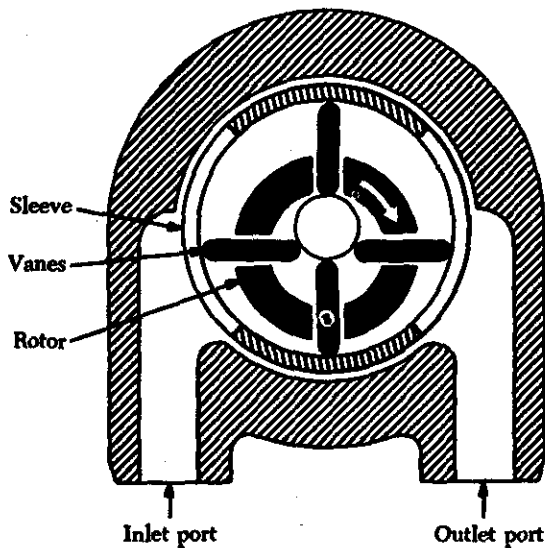


FIGURE 8-12. Vane-type power pump.

Piston Type Pump

The common features of design and operation that are applicable to all piston-type hydraulic pumps are described in the following paragraphs.

Piston-type power-driven pumps have flanged mounting bases for the purpose of mounting the pumps on the accessory drive cases of aircraft engines and transmissions. A pump drive shaft, which turns the mechanism, extends through the pump housing slightly beyond the mounting base (figure 8-13).

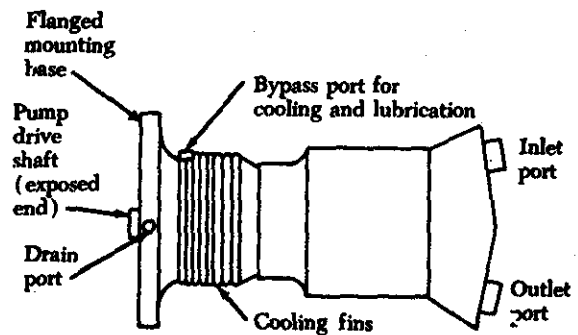


FIGURE 8-13. Typical piston-type hydraulic pump.

Torque from the driving unit is transmitted to the pump drive shaft by a drive coupling (figure 8-14). The drive coupling is a short shaft with a set of male splines on both ends. The splines on one end engage with female splines in a driving gear; the splines on the other end engage with female

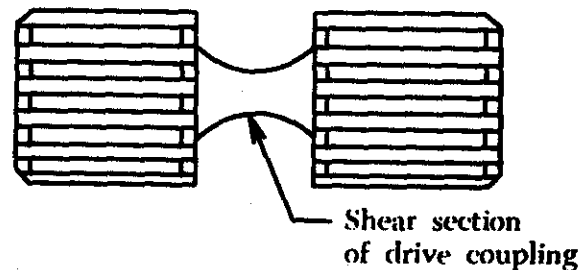


FIGURE 8-14. Pump drive coupling.

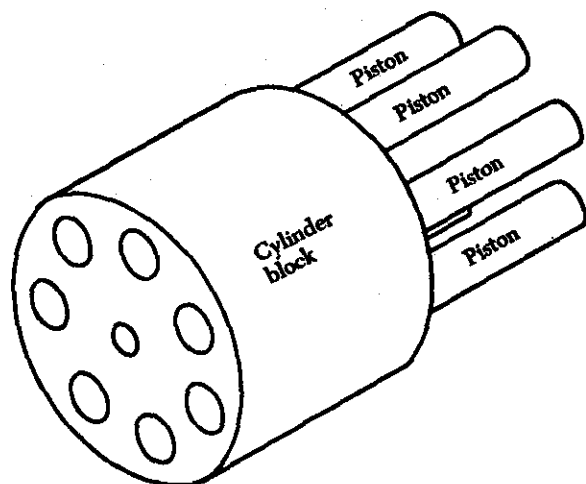


FIGURE 8-15. Axial-piston pump mechanism.

splines in the pump drive shaft. Pump drive couplings are designed to serve as safety devices. The shear section of the drive coupling, located midway between the two sets of splines, is smaller in diameter than the splines. If the pump becomes unusually hard to turn or becomes jammed, this section will shear, preventing damage to the pump or driving unit.

The basic pumping mechanism of piston-type pumps (figure 8-15) consists of a multiple-bore cylinder block, a piston for each bore, and a valving arrangement for each bore. The purpose of the valving arrangement is to let fluid into and out of the bores as the pump operates. The cylinder bores lie parallel to and symmetrically around the pump axis. The term "axial-piston pump" is often used in

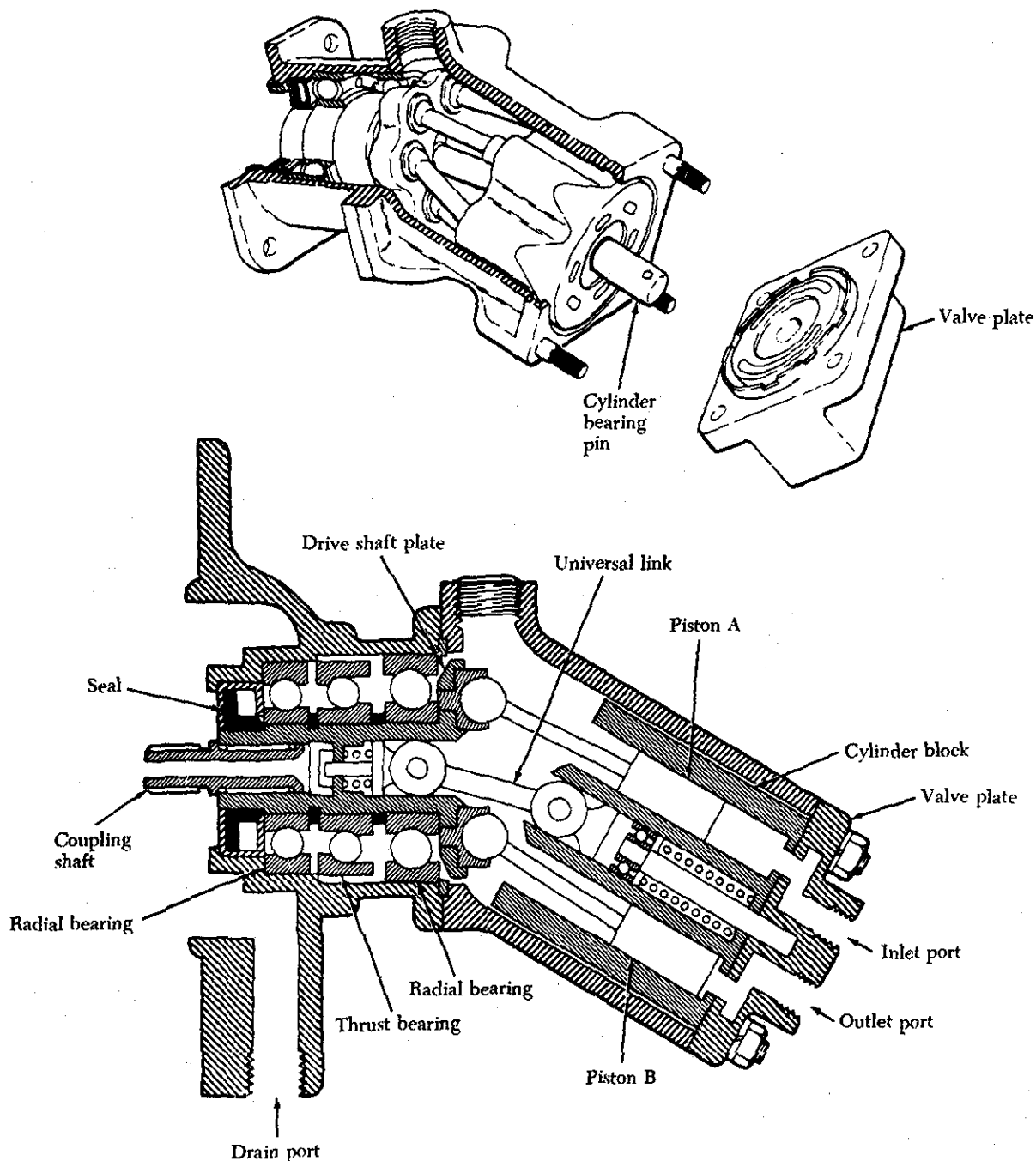


FIGURE 8-16. Typical angular-type pump.

referring to pumps of this arrangement. All aircraft axial-piston pumps have an odd number of pistons (5, 7, 9, 11, etc.).

Angular Type Piston Pump

A typical angular-type pump is shown in figure 8-16. The angular housing of the pump causes a corresponding angle to exist between the cylinder block and the drive shaft plate to which the pistons are attached. It is this angular configuration of the pump that causes the pistons to stroke as the pump shaft is turned.

When the pump is operated, all parts within the pump (except the outer races of the bearings which support the drive shaft, the cylinder bearing pin on which the cylinder block turns, and the oil seal) turn together as a rotating group. Because of the angle between the drive shaft and the cylinder block, at one point of rotation of the rotating group a minimum distance exists between the top of the cylinder block and the upper face of the drive shaft plate. At a point of rotation 180° away, the dis-

tance between the top of the cylinder block and the upper face of the drive shaft plate is at a maximum.

At any given moment of operation, three of the pistons will be moving away from the top face of the cylinder block, producing a partial vacuum in the bores in which these pistons operate. Fluid will be drawn into these bores at this time.

Movement of the pistons when drawing in and expelling fluid is overlapping in nature, and results in a practically non-pulsating discharge of fluid from the pump.

Cam Type Pump

Cam-type pumps (figure 8-17) utilize a cam to cause stroking of the pistons. There are two variations of cam-type pumps; one in which the cam turns and the cylinder block is stationary, and the other in which the cam is stationary and the cylinder block rotates.

As an example of the manner in which the pistons of a cam-type pump are caused to stroke, the operation of a rotating cam-type pump is described

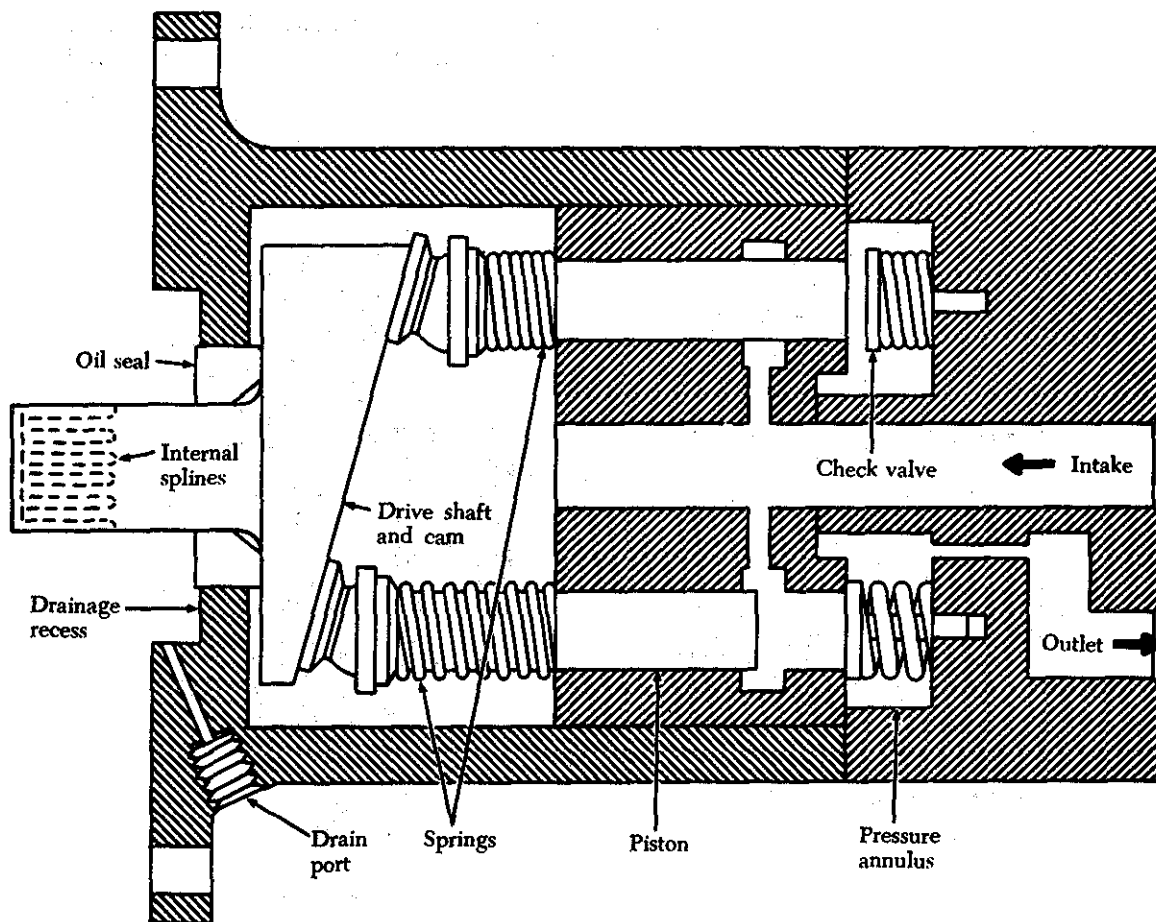


FIGURE 8-17. Typical cam-type pump.

as follows: As the cam turns, its high and low points pass alternately and, in turn, under each piston. When the rising ramp of the cam passes under a piston, it pushes the piston further into its bore, causing fluid to be expelled from the bore. When the falling ramp of the cam comes under a piston, the piston's return spring extends the piston outward of its bore. This causes fluid to be drawn into the bore. Because the movement of the pistons when drawing in and expelling fluid is overlapping in nature, the discharge of fluid from the cam-type pump is practically non-pulsating.

Each bore has a check valve that opens to allow fluid to be expelled from the bore by movement of the piston. These valves close during the inlet strokes of the pistons. Because of this, inlet fluid can be drawn into the bores only through the central inlet passage.

PRESSURE REGULATION

Hydraulic pressure must be regulated in order to use it to perform the desired tasks. Pressure regulating systems will always use three elemental devices; a pressure relief valve, a pressure regulator and a pressure gage.

Pressure Relief Valves

A pressure relief valve is used to limit the amount of pressure being exerted on a confined liquid. This is necessary to prevent failure of components or rupture of hydraulic lines under excessive pressures. The pressure relief valve is, in effect, a system safety valve.

The design of pressure relief valves incorporates adjustable spring-loaded valves. They are installed in such a manner as to discharge fluid from the pressure line into a reservoir return line when the pressure exceeds the predetermined maximum for which the valve is adjusted. Various makes and designs of pressure relief valves are in use, but, in general, they all employ a spring-loaded valving device operated by hydraulic pressure and spring tension. Pressure relief valves are adjusted by increasing or decreasing the tension on the spring to determine the pressure required to open the valve. Two general forms of pressure relief valves, the two-port and the four-port, are illustrated in figure 8-18.

Pressure relief valves may be classified as to their type of construction or uses in the system. However,

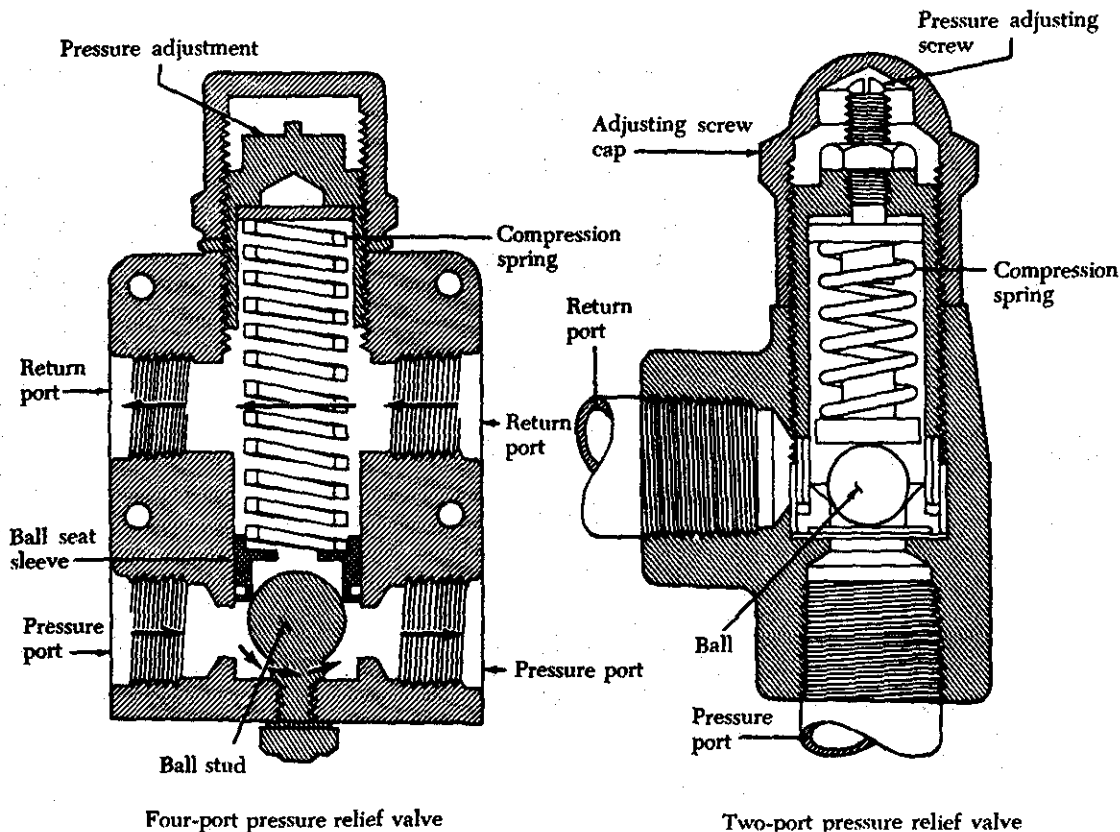


FIGURE 8-18. Pressure relief valves.

the general purpose and operation of all pressure relief valves are the same. The basic difference in construction of pressure relief valves is in the design of the valving. The most common types of valve are:

- (1) *Ball type.* In pressure relief valves with a ball-type valving device, the ball rests on a contoured seat. Pressure acting on the bottom of the ball pushes it off its seat, allowing the fluid to bypass.
- (2) *Sleeve type.* In pressure relief valves with a sleeve-type valving device, the ball remains stationary and a sleeve-type seat is moved up by the fluid pressure. This allows the fluid to bypass between the ball and the sliding sleeve-type seat.
- (3) *Poppet type.* In pressure relief valves with a poppet-type valving device, a cone-shaped poppet may have any of several design configurations; however, it is basically a cone and seat machined at matched angles to prevent leakage. As the pressure rises to its predetermined setting, the poppet is lifted off its seat, as in the ball-type device. This allows the fluid to pass through the opening created and out the return port.

Pressure relief valves cannot be used as pressure regulators in large hydraulic systems that depend upon engine-driven pumps for the primary source of pressure because the pump is constantly under load, and the energy expended in holding the pressure relief valve off its seat is changed into heat. This heat is transferred to the fluid and in turn to the packing rings causing them to deteriorate rapidly. Pressure relief valves, however, may be used as pressure regulators in small, low-pressure systems or when the pump is electrically driven and is used intermittently. Pressure relief valves may be used as:

- (1) *System relief valve.* The most common use of the pressure relief valve is as a safety device against the possible failure of a pump compensator or other pressure regulating device. All hydraulic systems which have hydraulic pumps incorporate pressure relief valves as safety devices.
- (2) *Thermal relief valve.* The pressure relief valve is used to relieve excessive pressures that may exist due to thermal expansion of the fluid.

Pressure Regulators

The term "pressure regulator" is applied to a device used in hydraulic systems that are pressurized by constant-delivery type pumps. One purpose of the pressure regulator is to manage the output of the pump to maintain system operating pressure within a predetermined range. The other purpose is to permit the pump to turn without resistance (termed unloading the pump) at times when pressure in the system is within normal operating range. The pressure regulator is so located in the system that pump output can get into the system pressure circuit only by passing through the regulator. The combination of a constant-delivery type pump and the pressure regulator is virtually the equivalent of a compensator-controlled, variable-delivery type pump.

Pressure Gage

The purpose of this gage is to measure the pressure, in the hydraulic system, used to operate hydraulic units on the aircraft. The gage uses a Bourdon tube and a mechanical arrangement to transmit the tube expansion to the indicator on the face of the gage. A vent in the bottom of the case maintains atmospheric pressure around the Bourdon tube. It also provides a drain for any accumulated moisture. There are several ranges of pressure used in hydraulic systems and gages are calibrated to match the system they accommodate.

Accumulator

The accumulator is a steel sphere divided into two chambers by a synthetic rubber diaphragm. The upper chamber contains fluid at system pressure, while the lower chamber is charged with air.

The function of an accumulator is to:

- a. Dampen pressure surges in the hydraulic system caused by actuation of a unit and the effort of the pump to maintain pressure at a preset level.
- b. Aid or supplement the power pump when several units are operating at once by supplying extra power from its "accumulated" or stored power.
- c. Store power for the limited operation of a hydraulic unit when the pump is not operating.
- d. Supply fluid under pressure to compensate for small internal or external (not desired) leaks which would cause the system to cycle continuously by action of the pressure switches continually "kicking in."

Diaphragm Accumulator

Diaphragm type accumulators consist of two hollow half-ball metal sections fastened together at the centerline. One of these halves has a fitting for attaching the unit to the system; the other half is equipped with an air valve for charging the unit with compressed air. Mounted between the two halves is a synthetic rubber diaphragm which divides the tank into two compartments. A screen covers the outlet on the fluid side of the accumulator. This prevents a part of the diaphragm from being pushed up into the system pressure port and being damaged. This could happen whenever there is an air charge in the unit and no balancing fluid pressure. In some units, a metal disc attached to the center of the diaphragm is used in place of the screen. (See figure 8-19).

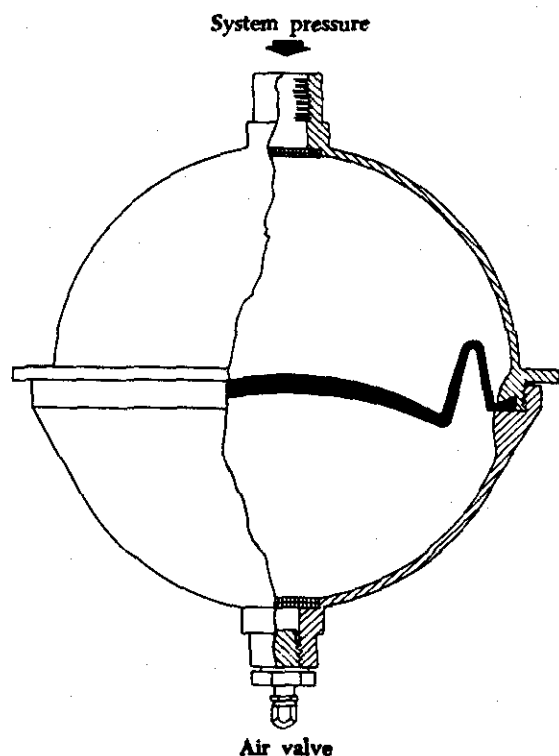


FIGURE 8-19. Diaphragm-type accumulator.

Bladder-Type Accumulators

The bladder-type accumulator operates on the same principle as the diaphragm type. It serves the same purpose, but varies in construction. This unit consists of a one-piece metal sphere with a fluid pressure inlet at the top. There is an opening at the bottom for inserting the bladder. A large screw-type plug at the bottom of the accumulator retains the bladder and also seals the unit. The high-pressure air valve is also mounted in the re-

tainer plug. A round metal disc attached to the top of the bladder prevents air pressure from forcing the bladder out through the pressure port. As fluid pressure rises, it forces the bladder downward against the air charge, filling the upper chamber with fluid pressure. The broken lines in figure 8-20 show the approximate shape of the bladder when the accumulator is charged.

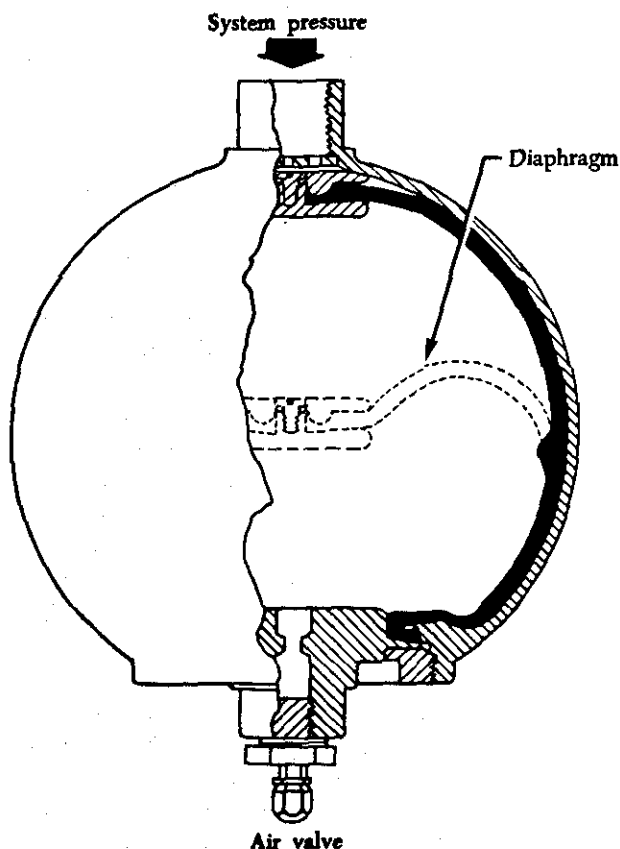
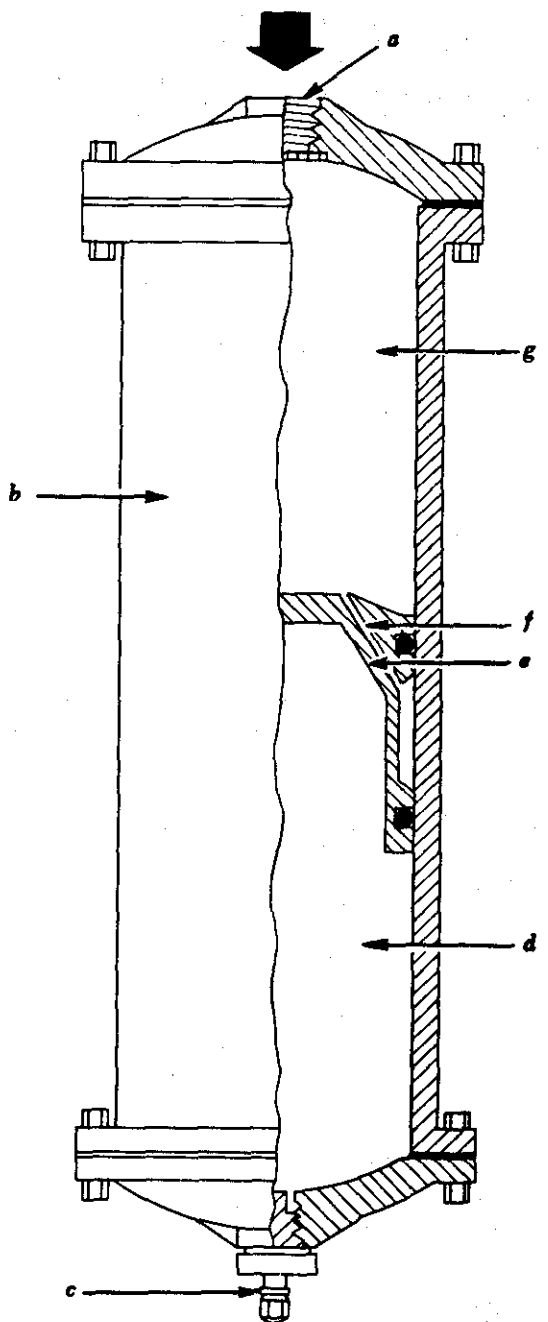


FIGURE 8-20. Bladder-type accumulator.

Piston-Type Accumulators

The piston-type accumulator also serves the same purpose and operates much like the diaphragm and bladder accumulators. As shown in figure 8-21 this unit is a cylinder (B) and piston assembly (E) with openings on each end. System fluid pressure enters the top port (A), and forces the piston down against the air charge in the bottom chamber (D). A high-pressure air valve (C) is located at the bottom of the cylinder for servicing the unit. There are two rubber seals (represented by the black dots) which prevent leakage between the two chambers (D and G). A passage (F) is drilled from the fluid side of the piston to the space between the seals. This provides lubrication between the cylinder walls and the piston.



- | | |
|---------------------------|--------------------|
| a. Fluid port | d. Air chamber |
| b. Cylinder | e. Piston assembly |
| c. High-pressure air vent | f. Drilled passage |
| | g. Fluid chamber |

FIGURE 8-21. Piston-type accumulator.

Maintenance of Accumulators

Maintenance consists of inspections, minor repairs, replacement of component parts, and testing. There is an element of danger in maintaining

accumulators. Therefore, proper precautions must be strictly observed to prevent injury and damage.

BEFORE DISASSEMBLING ANY ACCUMULATOR. MAKE SURE THAT ALL PRELOAD AIR (OR NITROGEN) PRESSURE HAS BEEN DISCHARGED. Failure to release the air could result in serious injury to the mechanic. (Before making this check, however, be certain you know the type of high-pressure air valve used.) When you know that all air pressure has been removed, go ahead and take the unit apart. Be sure, though, that you follow manufacturer's instructions for the specific unit you have.

Check Valves

For hydraulic components and systems to operate as intended, the flow of fluid must be rigidly controlled. Fluid must be made to flow according to definite plans. Many kinds of valve units are used for exercising such control. One of the simplest and most commonly used is the check valve which allows free flow of fluid in one direction, but no flow or a restricted flow in the opposite direction.

Check valves are made in two general designs to serve two different needs. In one, the check valve is complete within itself. It is inter-connected with other components, with which it operates, by means of tubing or hose. Check valves of this design are commonly called in-line check valves. There are two types of in-line check valves, the simple-type in-line check valve and the orifice-type in-line valve. (See figure 8-22.)

In the other design, the check valve is not complete within itself because it does not have a housing exclusively its own. Check valves of this design are commonly called integral check valves. This valve is actually an integral part of some major component and, as such, shares the housing of that component.

In-Line Check Valve

The simple-type in-line check valve (often called check valve) is used when a full flow of fluid is desired in only one direction (figure 8-22A). Fluid enters the inlet port of the check valve forcing the valve off its seat against the restraint of the spring. This permits fluid to flow through the passageway thus opened. The instant fluid stops moving in this direction, the spring returns the valve to its seat. This blocks the opening in the valve seat, and therefore blocks reverse flow of fluid through the valve.

Orifice-Type Check Valve

The orifice-type in-line check valve (figure 8-22B) is used to allow normal operating speed

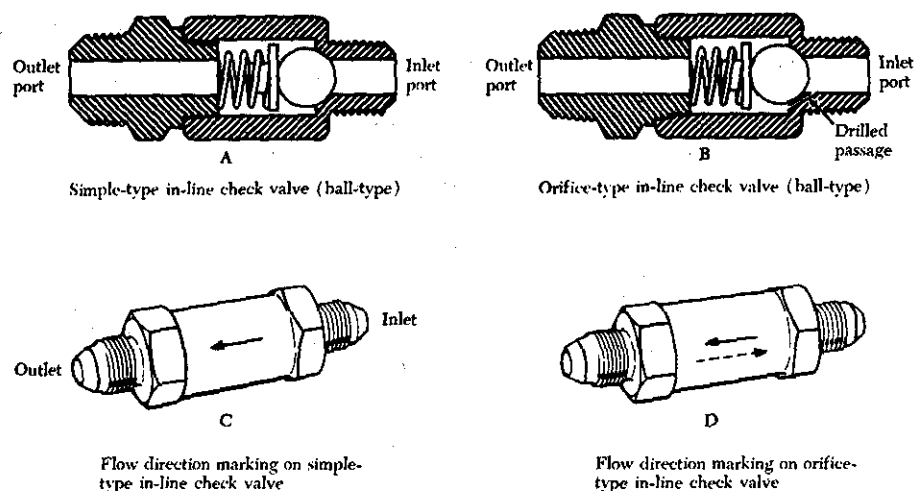


FIGURE 8-22. Typical in-line check valves.

of a mechanism by providing free flow of fluid in one direction, while allowing limited operating speed through restricted flow of fluid in the opposite direction. The operation of the orifice-type in-line check valve is the same as the simple-type in-line check valve, except for the restricted flow allowed when closed. This is accomplished by a second opening in the valve seat that is never closed, so that some reverse flow can take place through the valve. The second opening is much smaller than the opening in the valve seat. As a rule, this opening is of a specific size thus maintaining close control over the rate at which fluid can flow back through the valve. This type of valve is sometimes called a damping valve.

The direction of fluid flow through in-line check valves is normally indicated by stamped arrow markings on the housings (figure 8-22C and D). On the simple-type in-line check valve, a single arrow points in the direction which fluid can flow. The orifice-type in-line check valve is usually marked with two arrows. One arrow is more pronounced than the other, and indicates the direction of unrestricted flow. The other arrow is either of smaller size than the first or of broken-line construction, and points in the direction of restricted reverse fluid flow.

In addition to the ball-type in-line check valves shown in figure 8-22, other types of valves, such as disks, needles, and poppets are used.

The operating principles of integral check valves are the same as the operating principles of in-line check valves.

Line-Disconnect or Quick-Disconnect Valves

These valves are installed in hydraulic lines to prevent loss of fluid when units are removed. Such

valves are installed in the pressure and suction lines of the system just in front of and immediately behind the power pump. These valves can also be used in other ways than just for unit replacement. A power pump can be disconnected from the system and a hydraulic test stand connected in its place. These valve units consist of two interconnecting sections coupled together by a nut when installed in the system. Each valve section has a piston and poppet assembly. These are spring loaded to the CLOSED position when the unit is disconnected.

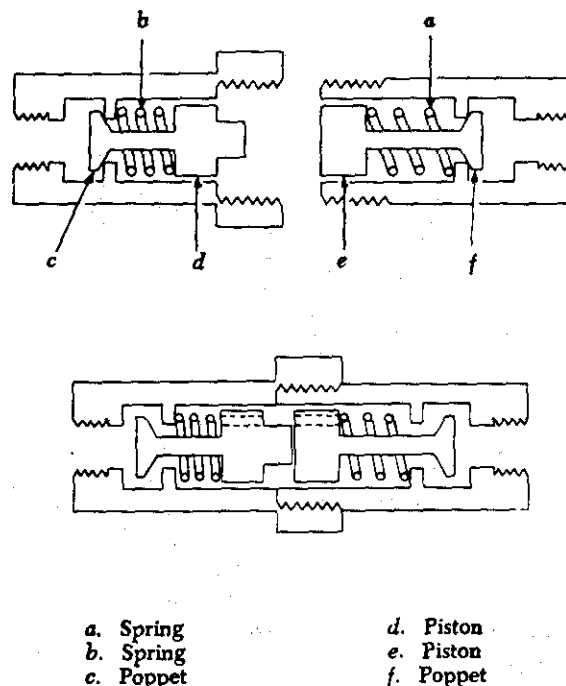


FIGURE 8-23. Line disconnect valve.

The top illustration of figure 8-23 shows the valve in the LINE-DISCONNECTED position. The two springs (a and b) hold both poppets (c and f) in the CLOSED position as shown. This prevents loss of fluid through the disconnected line. The bottom illustration of figure 8-23 shows the valve in the LINE-CONNECTED position. When the valve is being connected, the coupling nut draws the two sections together. The extension (d or e) on one of the pistons forces the opposite piston back against its spring. This action moves the poppet off its seat and permits the fluid to flow through that section of the valve. As the nut is drawn up tighter, one piston hits a stop; now the other piston moves back against its spring and, in turn, allows fluid to flow. Thus, fluid is allowed to continue through the valve and on through the system.

Bear in mind that the above disconnect valve is only one of the many types presently used. Although all line-disconnect valves operate on the same principle, the details will vary. Each manufacturer has his own design features.

A very important factor in the use of the line-disconnect valve is its proper connection. Hydraulic pumps can be seriously damaged if the line disconnects are not properly connected. If you are in doubt about the line disconnect's operation, consult the aircraft maintenance manual.

The extent of maintenance to be performed on a quick disconnect valve is very limited. The internal parts of this type valve are precision built and factory assembled. They are made to very close tolerances, therefore, no attempt should be made to disassemble or replace internal parts in either coupling half. However, the coupling halves, lock-springs, union nuts, and dust caps may be replaced. When replacing the assembly or any of the parts, follow the instructions in the applicable maintenance manual.

ACTUATING CYLINDERS

An actuating cylinder transforms energy in the form of fluid pressure into mechanical force, or action, to perform work. It is used to impart powered linear motion to some movable object or mechanism.

A typical actuating cylinder consists fundamentally of a cylinder housing, one or more pistons and piston rods, and some seals. The cylinder housing contains a polished bore in which the piston operates, and one or more ports through which fluid enters and leaves the bore. The piston and rod form an assembly. The piston moves forward and backward within the cylinder bore and an attached piston rod moves into and out of the cylinder housing through an opening in one end

of the cylinder housing. Seals are used to prevent leakage between the piston and the cylinder bore, and between the piston rod and the end of the cylinder. Both the cylinder housing and the piston rod have provisions for mounting and for attachment to an object or mechanism which is to be moved by the actuating cylinder.

Actuating cylinders are of two major types: (1) Single-action and (2) Double-action. The single-action (single port) actuating cylinder is capable of producing powered movement in one direction only. The double-action (two port) actuating cylinder is capable of producing powered movement in two directions.

Single-Action Actuating Cylinder

A single-action actuating cylinder is illustrated in figure 8-24. Fluid under pressure enters the port at the left and pushes against the face of the piston, forcing the piston to the right. As the piston moves, air is forced out of the spring chamber through the vent hole, compressing the spring. When pressure on the fluid is released to the point that it exerts less force than is present in the compressed spring, the spring pushes the piston toward the left. As the piston moves to the left, fluid is forced out of the fluid port. At the same time, the moving piston pulls air into the spring chamber through the venthole. A three-way control valve is normally used for controlling the operation of a single-action actuating cylinder.

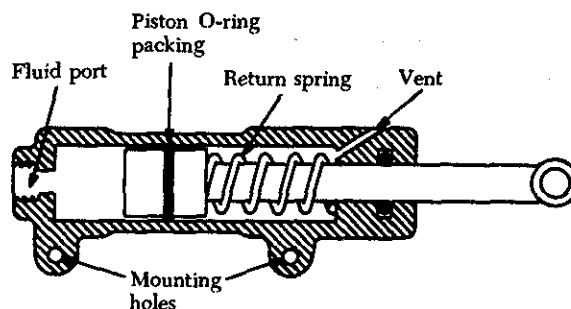


FIGURE 8-24. Single-action actuating cylinder.

Double-Action Actuating Cylinder

A double-action (two-port) actuating cylinder is illustrated in figure 8-25. The operation of a double-action actuating cylinder is usually controlled by a four-way selector valve. Figure 8-26 shows an actuating cylinder interconnected with a selector valve. Operation of the selector valve and actuating cylinder is discussed below.

Placing the selector valve in the "on" position (figure 8-26A) admits fluid pressure to the left-hand chamber of the actuating cylinder. This results in the piston being forced toward the right.

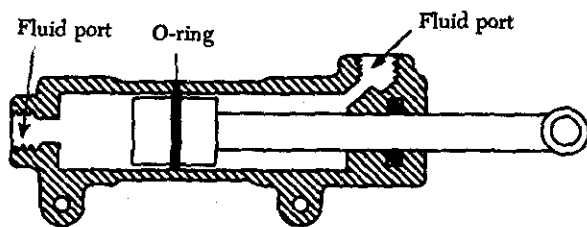


FIGURE 8-25. Double-action actuating cylinder.

As the piston moves toward the right, it pushes return fluid out of the right-hand chamber and through the selector valve to the reservoir.

When the selector valve is placed in its other "on" position, as illustrated in figure 8-26B, fluid pressure enters the right-hand chamber, forcing the piston toward the left. As the piston moves toward the left, it pushes return fluid out of the left-hand chamber and through the selector valve to the reservoir. Besides having the ability to move a load into position, a double-acting cylinder also has the ability to hold a load in position. This capability exists because when the selector valve used to control operation of the actuating cylinder is placed in the "off" position, fluid is trapped in the chambers on both sides of the actuating cylinder piston.

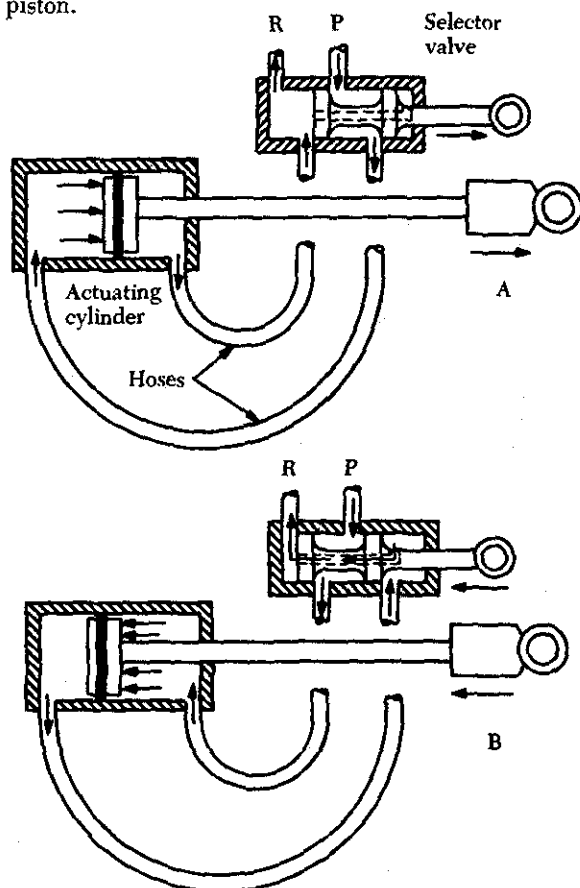


FIGURE 8-26. Control of actuating cylinder movement.

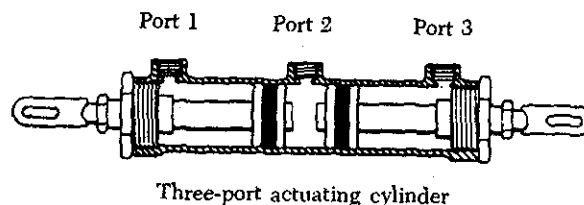
In addition to the two general design types of actuating cylinders discussed (single-action and double-action), other types are available. Figure 8-27 shows three additional types.

SELECTOR VALVES

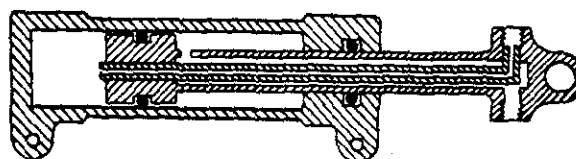
Selector valves are used to control the direction of movement of an actuating unit. A selector valve provides a pathway for the simultaneous flow of hydraulic fluid into and out of a connected actuating unit. A selector valve also provides a means of immediately and conveniently switching the directions in which the fluid flows through the actuator, reversing the direction of movement.

One port of the typical selector valve is connected with a system pressure line for the input of fluid pressure. A second port of the valve is connected to a system return line for the return of fluid to the reservoir. The ports of an actuating unit through which fluid enters and leaves the actuating unit are connected by lines to other ports of the selector valve.

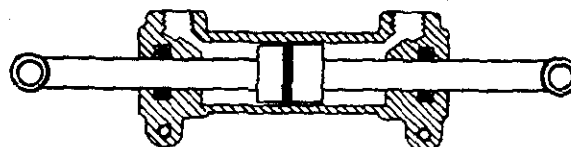
Selector valves have various numbers of ports. The number of ports is determined by the particular requirements of the system in which the valve is



Three-port actuating cylinder



Actuating cylinder having ports in piston rod



Double-action actuating cylinder having two exposed piston rod ends

FIGURE 8-27. Types of actuating cylinders.

used. Selector valves having four ports are the most commonly used. The term four-way is often used instead of four-port in referring to selector valves.

The ports of selector valves (figure 8-28) are individually marked to provide ready identification. The most commonly used markings are: PRESSURE (or PRESS, or P), RETURN (or RET, or R), CYLINDER 1 (or CYL 1), and CYLINDER 2 (or CYL 2). The use of the word "cylinder" in the designation of selector valve ports does not indicate, as it may suggest, that only hydraulic cylinders are to be connected to the ports so marked. In fact, any type of hydraulic actuating unit may be connected to the ports. The numbers 1 and 2 are a convenient means of differentiating between two ports of the selector valve.

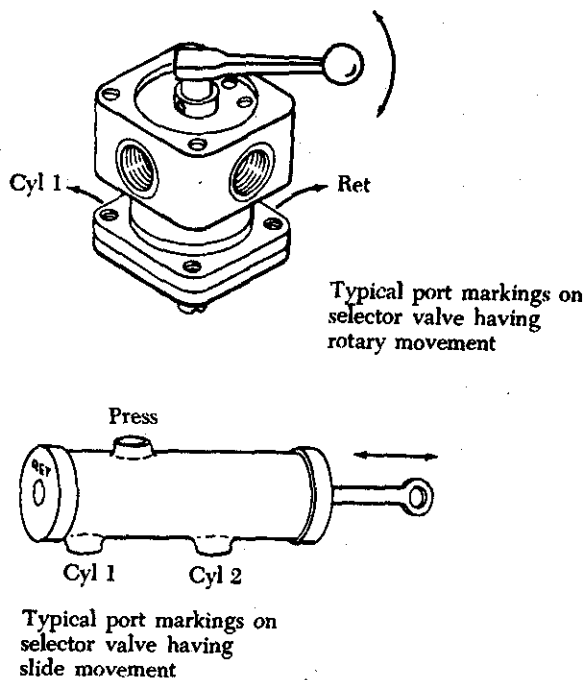


FIGURE 8-28. Typical port markings on selector valves.

Four-Way Closed-Center Selector Valve

Because the four-way, closed-center selector valve is one of the most commonly used selector valves in an aircraft hydraulic system, it is discussed in detail in the following paragraphs. Valving devices of various kinds, such as balls, poppets, rotors, or spools, are used in the four-way, closed-center selector valves.

Figure 8-29A illustrates a four-way, closed-center selector valve in the "off" position. All of the valve ports are blocked, and fluid can not flow into or out of the valve.

In figure 8-29B, the selector valve is placed in one of its "on" positions. The PRESS port and CYL 1 port become interconnected within the valve. As a result, fluid flows from the pump into the selector valve PRESS port, out of the selector valve CYL 1 port, and into port A of the motor. This flow of fluid causes the motor to turn in a clockwise direction. Simultaneously, return fluid is forced out of port B of the motor and enters the selector valve CYL 2 port. Fluid then proceeds through the passage in the valve rotor and leaves the valve through the RET port.

In figure 8-29C, the selector valve is placed in the other "on" position. The PRESS port and CYL 2 port become interconnected. This causes fluid pressure to be delivered to port B of the motor, which results in the motor turning counterclockwise. Return fluid leaves port A of the motor, enters the selector valve CYL 1 port, and leaves through the selector valve RET port.

Spool-Type Selector Valve

The valving device of the spool-type selector valve is spool-shaped (figure 8-30). The spool is a one-piece, leak-tight, free-sliding fit in the selector valve housing and can be moved lengthwise in the housing by means of the extended end which projects through the housing. A drilled passage in the spool interconnects the two end chambers of the selector valve. Selector valve spools are sometimes called pilot valves.

When the spool is moved to the selector valve "off" position, the two cylinder ports are directly blocked by the lands (flanges) of the spool (figure 8-30A). This indirectly blocks the PRESS and RET ports and fluid can not flow into or out of the valve.

Moving the spool toward the right moves the spool lands away from the CYL 1 and CYL 2 ports (figure 8-23B). The PRESS port and CYL 2 port then become interconnected. This permits fluid pressure to pass on to the actuating unit. The RET port and CYL 1 port also become interconnected. This provides an open route for the return of fluid from the actuating unit to the system reservoir.

Moving the spool toward the left moves the spool lands away from the CYL 1 and CYL 2 ports (figure 8-30C). The PRESS port and CYL 1 port then become interconnected. This permits fluid pressure to flow to the actuating unit. The RET port and CYL 2 port also become interconnected, providing a route for the return of fluid from the actuating unit to the reservoir.

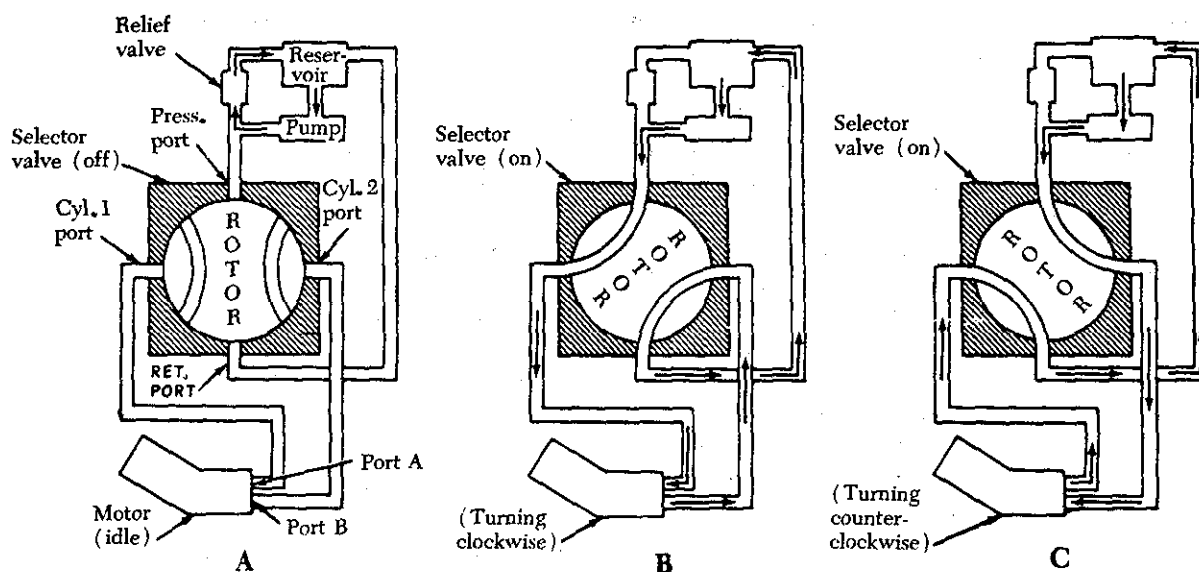


FIGURE 8-29. Typical rotor-type, closed-center selector valve operation.

AIRCRAFT PNEUMATIC SYSTEMS

Some aircraft manufacturers equip their aircraft with a pneumatic system. Such systems operate a great deal like hydraulic systems, except they employ air instead of a liquid for transmitting power. Pneumatic systems are sometimes used for:

- (1) Brakes.
- (2) Opening and closing doors.
- (3) Driving hydraulic pumps, alternators, starters, water injection pumps, etc.
- (4) Operating emergency devices.

Both pneumatic and hydraulic systems are similar units and use confined fluids. The word "confined" means trapped or completely enclosed. The word "fluid" implies such liquids as water, oil, or anything that flows. Since both liquids and gases will flow, they are considered as fluids; however, there is a great deal of difference in the characteristics of the two. Liquids are practically incompressible; a quart of water still occupies about a quart of space regardless of how hard it is compressed. But gases are highly compressible; a quart of air can be compressed into a thimbleful of space. In spite of this difference, gases and liquids are both fluids and can be confined and made to transmit power.

The type of unit used to provide pressurized air for pneumatic systems is determined by the system's air pressure requirements.

High Pressure System

For high-pressure systems, air is usually stored in

metal bottles (figure 8-31) at pressures ranging from 1,000 to 3,000 p.s.i., depending on the particular system. This type of air bottle has two valves, one of which is a charging valve. A ground-operated compressor can be connected to this valve to add air to the bottle. The other valve is a control valve. It acts as a shutoff valve, keeping air trapped inside the bottle until the system is operated.

Although the high-pressure storage cylinder is light in weight, it has a definite disadvantage. Since the system cannot be re-charged during flight, operation is limited by the small supply of bottled air. Such an arrangement can not be used for the continuous operation of a system. Instead, the supply of bottled air is reserved for emergency operation of such systems as the landing gear or brakes. The usefulness of this type of system is increased, however, if other air-pressurizing units are added to the aircraft.

On some aircraft, permanently installed air compressors have been added to re-charge air bottles whenever pressure is used for operating a unit. Several types of compressors are used for this purpose. Some have two stages of compression, while others have three. Figure 8-32 shows a simplified schematic of a two-stage compressor; the pressure of the incoming air is boosted first by cylinder No. 1 and again by cylinder No. 2.

The compressor in figure 8-32 has three check valves. Like the check valves in a hydraulic hand pump, these units allow fluid to flow in only one direction. Some source of power, such as an electric

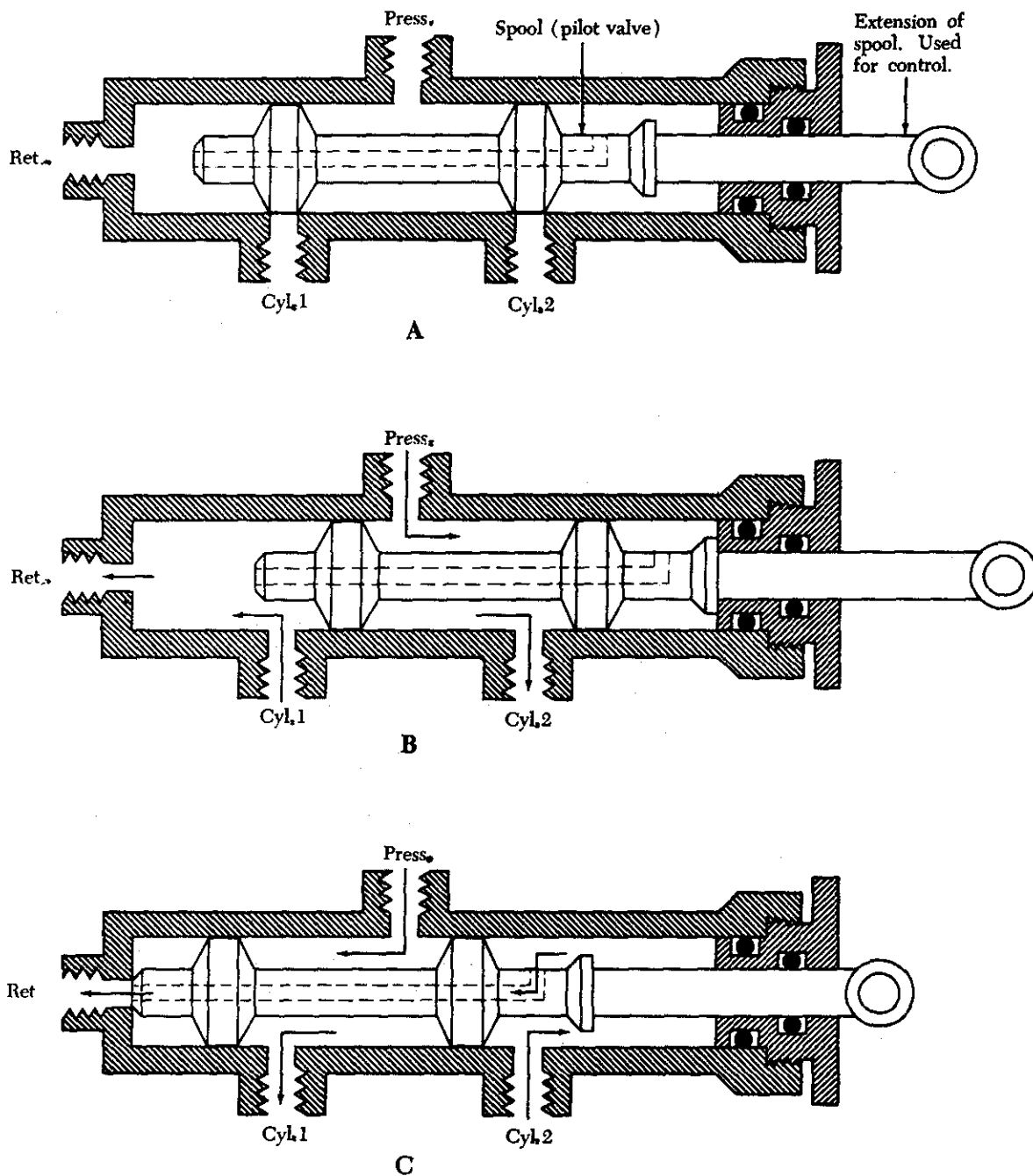


FIGURE 8-30. Typical spool-type, closed-center selector valve.

motor or aircraft engine, operates a drive shaft. As the shaft turns, it drives the pistons in and out of their cylinders. When piston No. 1 moves to the right, the chamber in cylinder No. 1 becomes larger, and outside air flows through the filter and check valve into the cylinder. As the drive shaft continues to turn, it reverses the direction of piston

movement. Piston No. 1 now moves deeper into its cylinder, forcing air through the pressure line and into cylinder No. 2. Meanwhile piston No. 2 is moving out of cylinder No. 2 so that cylinder No. 2 can receive the incoming air. But cylinder No. 2 is smaller than cylinder No. 1; thus, the air must be highly compressed to fit into cylinder No. 2.

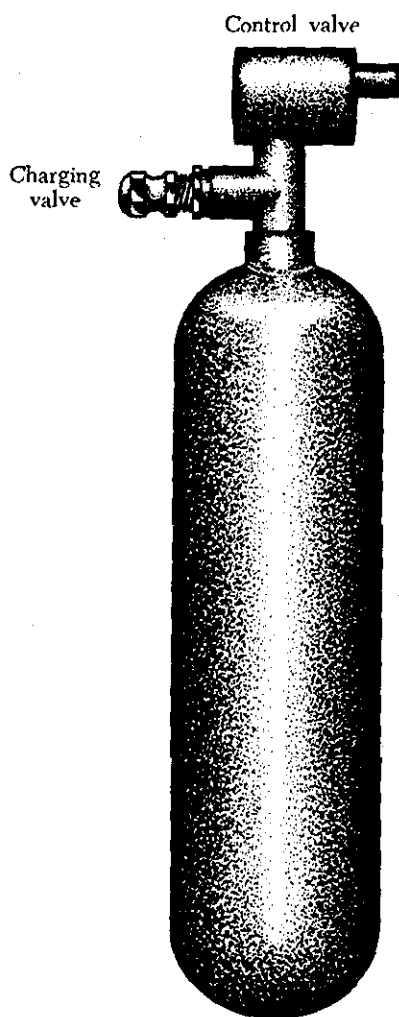


FIGURE 8-31. Steel cylinder for high-pressure air storage.

Because of the difference in cylinder size, piston No. 1 gives the air its first stage of compression. The second stage occurs as piston No. 2 moves deeper into its cylinder, forcing high-pressure air to flow through the pressure line and into the air storage bottle.

Medium Pressure System

A medium-pressure pneumatic system (100 — 150 p.s.i.) usually does not include an air bottle. Instead, it generally draws air from a jet engine compressor section. In this case, air leaves the engine through a takeoff and flows into tubing, carrying air first to the pressure-controlling units and then to the operating units. Figure 8-33 shows a jet engine compressor with a pneumatic system takeoff.

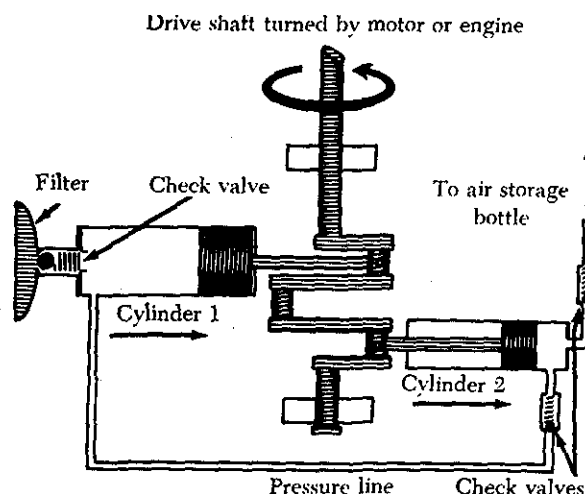


FIGURE 8-32. Schematic of two-stage air compressor.

Low Pressure System

Many aircraft equipped with reciprocating engines obtain a supply of low-pressure air from vane-type pumps. These pumps are driven by electric motors or by the aircraft engine. Figure 8-34 shows a schematic view of one of these pumps, which consists of a housing with two ports, a drive shaft, and two vanes. The drive shaft and the vanes contain slots so the vanes can slide back and forth through the drive shaft. The shaft is eccentrically mounted in the housing, causing the vanes to form four different sizes of chambers (A, B, C, and D). In the position shown, B is the largest chamber and is connected to the supply port. As depicted in the illustration, outside air can enter chamber B of the pump.

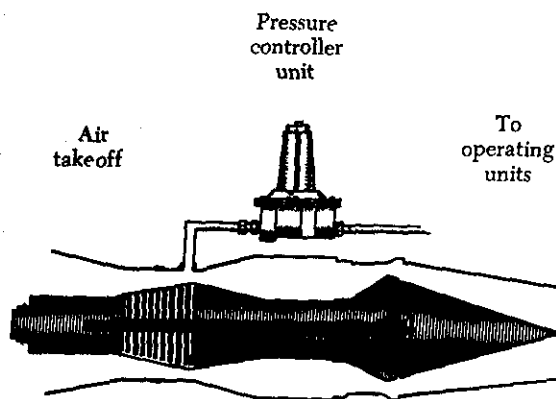


FIGURE 8-33. Jet engine compressor with pneumatic system takeoff.

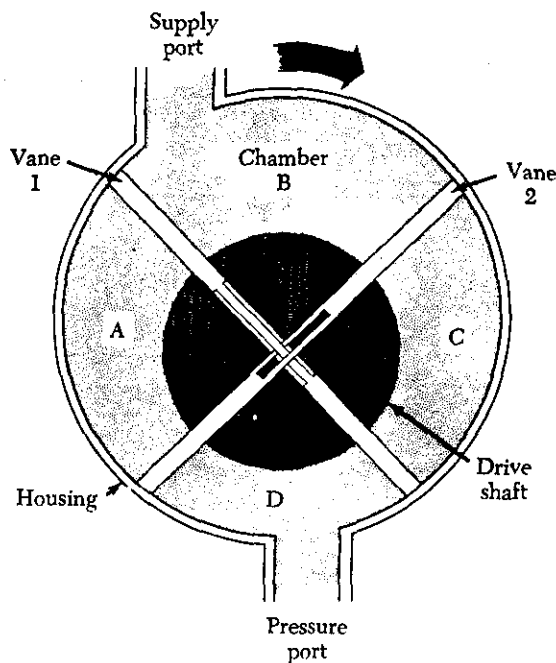


FIGURE 8-34. Schematic of vane-type air pump.

When the pump begins to operate, the drive shaft rotates and changes positions of the vanes and sizes of the chambers. Vane No. 1 then moves to the right (figure 8-34), separating chamber B from the supply port. Chamber B now contains trapped air. As the shaft continues to turn, chamber B moves downward and becomes increasingly smaller, gradually compressing its air. Near the bottom of the pump, chamber B connects to the pressure port and sends compressed air into the pressure line. Then chamber B moves upward again becoming increasingly larger in area. At the supply port it receives another supply of air. There are four such chambers in this pump, and each goes through this same cycle of operation. Thus, the pump delivers to the pneumatic system a continuous supply of compressed air at from 1 to 10 p.s.i.

PNEUMATIC SYSTEM COMPONENTS

Pneumatic systems are often compared to hydraulic systems, but such comparisons can only hold true in general terms. Pneumatic systems do not utilize reservoirs, hand pumps, accumulators, regulators, or engine-driven or electrically-driven power pumps for building normal pressure. But similarities do exist in some components.

Relief Valves

Relief valves are used in pneumatic systems to prevent damage. They act as pressure-limiting units and prevent excessive pressures from bursting lines and blowing out seals. Figure 8-35 illustrates a cutaway view of a pneumatic system relief valve.

At normal pressures, a spring holds the valve closed (figure 8-35), and air remains in the pressure line. If pressure grows too high, the force it creates on the disk overcomes spring tension and opens the relief valve. Then, excess air flows through the valve and is exhausted as surplus air into the atmosphere. The valve remains open until the pressure drops to normal.

Control Valves

Control valves are also a necessary part of a typical pneumatic system. Figure 8-36 illustrates how a valve is used to control emergency air brakes. The control valve consists of a three-port housing, two poppet valves, and a control lever with two lobes.

In figure 8-36A, the control valve is shown in the "off" position. A spring holds the left poppet closed so that compressed air entering the pressure port cannot flow to the brakes. In figure 8-36B, the control valve has been placed in the "on" position. One lobe of the lever holds the left poppet open,

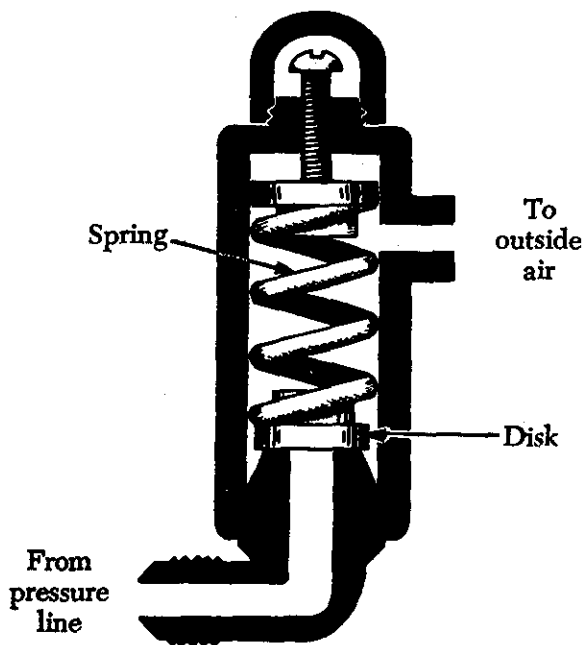
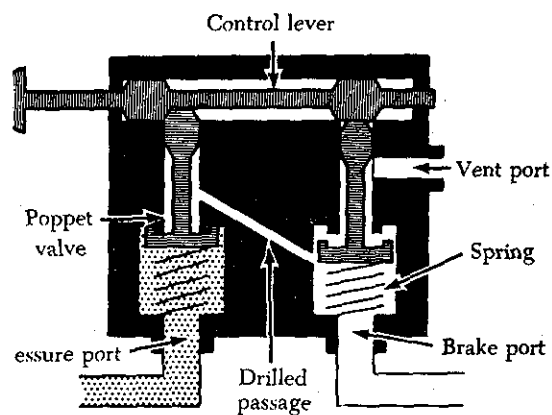
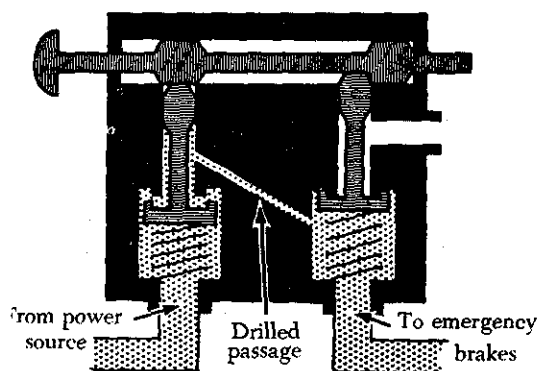


FIGURE 8-35. Pneumatic system relief valve.



A. Control valve "off"



B. Control valve "on"

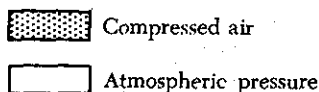


FIGURE 8-36. Flow diagram of a pneumatic control valve.

and a spring closes the right poppet. Compressed air now flows around the opened left poppet, through a drilled passage, and into a chamber below the right poppet. Since the right poppet is closed, the high-pressure air flows out of the brake port and into the brake line to apply the brakes.

To release the brakes, the control valve is returned to the "off" position (figure 8-36A). The left poppet now closes, stopping the flow of high-pressure air to the brakes. At the same time, the right poppet is opened, allowing compressed air in the brake line to exhaust through the vent port and into the atmosphere.

Check Valves

Check valves are used in both hydraulic and pneumatic systems. Figure 8-37 illustrates a flap-type pneumatic check valve. Air enters the left port of the check valve, compresses a light spring, forcing the check valve open and allowing air to flow out the right port. But if air enters from the right, air pressure closes the valve, preventing a flow of air out the left port. Thus, a pneumatic check valve is a one-direction flow control valve.

Restrictors

Restrictors are a type of control valve used in pneumatic systems. Figure 8-38 illustrates an orifice type restrictor with a large inlet port and a small outlet port. The small outlet port reduces the rate of airflow and the speed of operation of an actuating unit.

Variable Restrictor

Another type of speed-regulating unit is the variable restrictor shown in figure 8-39. It contains an adjustable needle valve, which has threads around the top and a point on the lower end. Depending on the direction turned, the needle valve moves the sharp point either into or out of a small opening to decrease or increase the size of the opening. Since air entering the inlet port must pass through this opening before reaching the outlet port, this adjustment also determines the rate of airflow through the restrictor.

Filters

Pneumatic systems are protected against dirt by means of various types of filters. A micron filter (figure 8-40) consists of a housing with two ports, a replaceable cartridge, and a relief valve. Normally, air enters the inlet, circulates around the cellulose cartridge, then flows to the center of the cartridge and out the outlet port. If the cartridge becomes clogged with dirt, pressure forces the relief valve open and allows unfiltered air to flow out the outlet port.

A screen-type filter (figure 8-41) is similar to the micron filter but contains a permanent wire screen instead of a replaceable cartridge. In the screen filter a handle extends through the top of the housing and can be used to clean the screen by rotating it against metal scrapers.

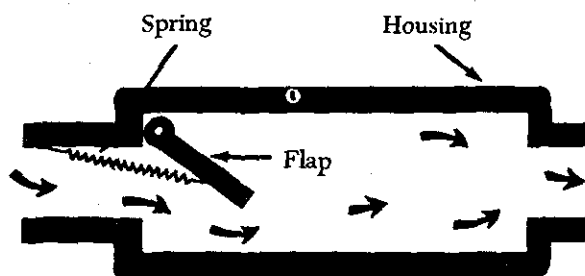


FIGURE 8-37. Pneumatic system check valve.

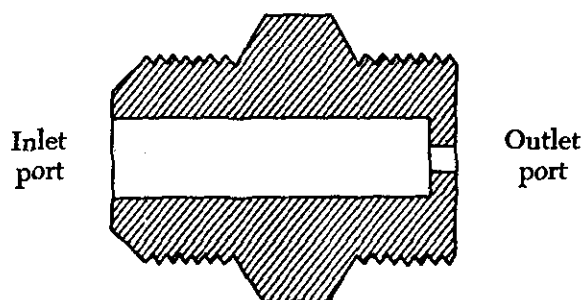


FIGURE 8-38. Orifice restrictor.

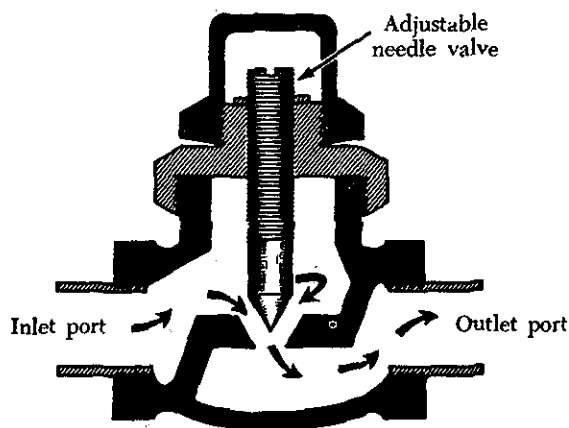


FIGURE 8-39. Variable pneumatic restrictor.

If the main hydraulic braking system fails, power brakes are usually equipped with some type of emergency pressurizing system for stopping the aircraft. In many instances, these emergency systems

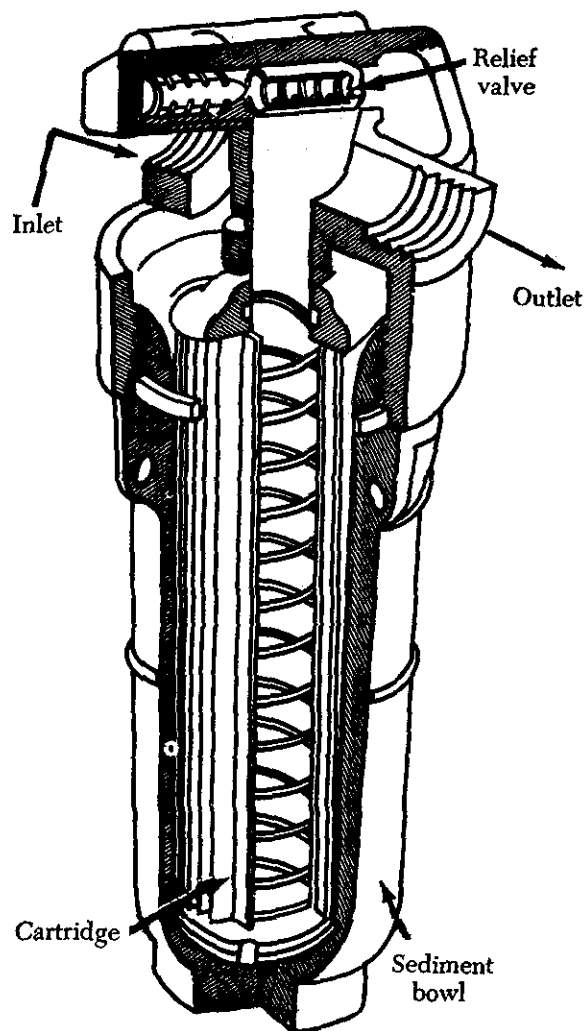


FIGURE 8-40. Micronic filter.

are compressed air systems. Figure 8-42 illustrates one type of system which uses compressed air.

Air Bottle

The air bottle usually stores enough compressed air for several applications of the brakes. A high-pressure air line connects the bottle to an air valve which controls operation of the emergency brakes.

If the normal brake system fails, place the control handle for the air valve in the "on" position. The valve then directs high-pressure air into lines leading to the brake assemblies. But before air enters the brake assemblies, it must first flow through a shuttle valve.

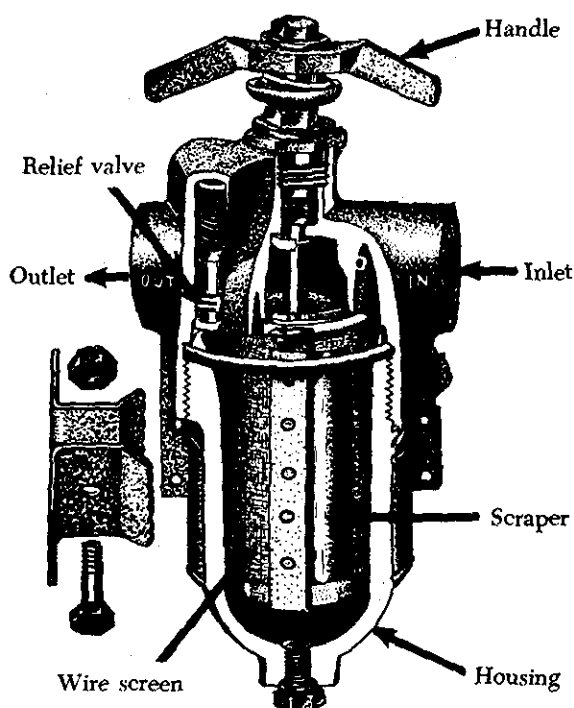


FIGURE 8-41. Screen-type filter.

Brake Shuttle Valve

The circled inset at the upper right of figure 8-42 shows one type of shuttle valve. The valve consists of a shuttle enclosed by a four-port hous-

ing. The shuttle is a sort of floating piston that can move up or down in the hollow housing. Normally, the shuttle is down, and in this position it seals off the lower air port and directs hydraulic fluid from the upper port into the two side ports, each of which leads to a brake assembly. But when the emergency pneumatic brakes are applied, high-pressure air raises the shuttle, seals off the hydraulic line, and connects air pressure to the side ports of the shuttle valve. This action sends high-pressure air into the brake cylinder to apply the brakes.

After application and when the emergency brakes are released, the air valve closes, trapping pressure in the air bottle. At the same time, the air valve vents the pneumatic brake line to outside air pressure. Then as air pressure in the brake line drops, the shuttle valve moves to the lower end of the housing, again connecting the brake cylinders to the hydraulic line. Air pressure remaining in the brake cylinders then flows out the upper port of the shuttle valve and into the hydraulic return line.

Lines and Tubing

Lines for pneumatic systems consist of rigid metal tubing and flexible rubber hose. Fluid lines and fittings are covered in detail in Chapter 5 of the Airframe and Powerplant Mechanics General Handbook, AC 65-9A.

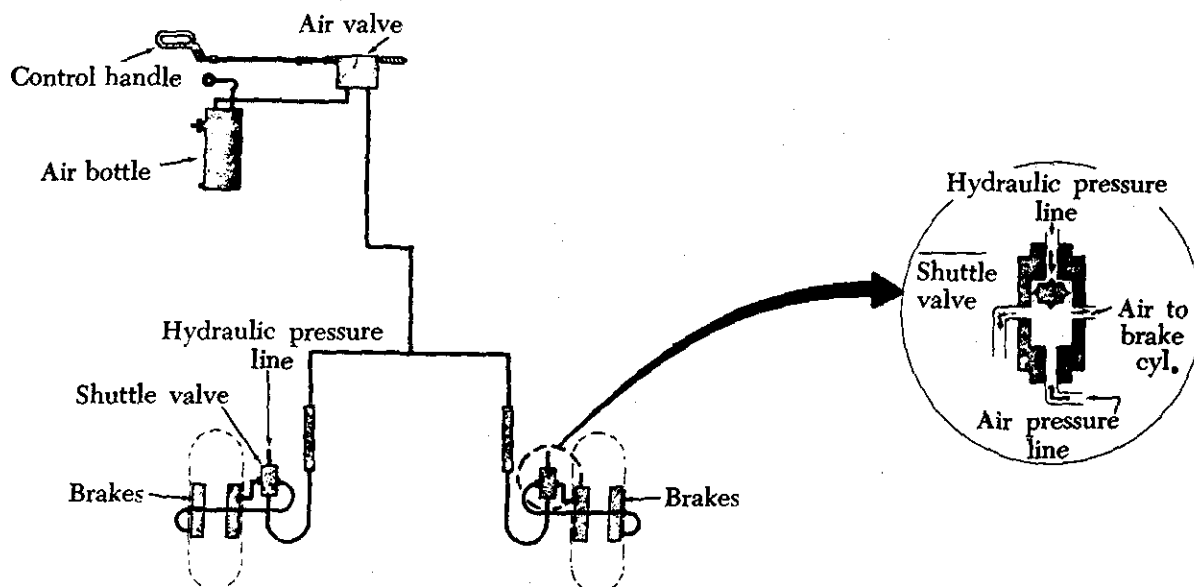


FIGURE 8-42. Simplified emergency brake system.

A typical turbine-engine pneumatic power system supplies compressed air for various normal and emergency actuating systems. The compressed air is stored in storage cylinders in the actuating systems until required by actuation of the system. These cylinders and the power system manifold are initially charged with compressed air or nitrogen from an external source through a single air-charge valve. In flight, the air compressor replaces the air pressure and volume lost through leakage, thermal contraction, and actuating system operation.

The air compressor is supplied with supercharged air from the engine bleed air system. This ensures an adequate air supply to the compressor at all altitudes. The air compressor may be driven either by an electric motor or a hydraulic motor. The system described here is hydraulically driven. The following description is illustrated by the pneumatic power system shown in figure 8-43.

The compressor inlet air is filtered through a high-temperature, 10-micron filter and the air pressure is regulated by an absolute pressure regulator



to provide a stabilized source of air for the compressor. (See figure 8-43.)

The aircraft utility hydraulic system provides power to operate the hydraulic-motor-driven air compressor. The air compressor hydraulic actuating system consists of a solenoid-operated selector valve, flow regulator, hydraulic motor, and motor bypass (case drain) line check valve. When energized, the selector valve allows the system to be pressurized to run the hydraulic motor; when de-energized the valve blocks off utility system pressure, stopping the motor. The flow regulator, compensating for the varying hydraulic system flow and pressures, meters the flow of fluid to the hydraulic motor to prevent excessive speed variation and/or overspeeding of the compressor. A check valve in the motor bypass line prevents system return line pressures from entering the motor and stalling it.

The air compressor is the pneumatic system's pressurizing air source. The compressor is activated or deactivated by the manifold pressure-sensing switch, which is an integral part of the moisture separator assembly.

The moisture separator assembly is the pneumatic system's pressure-sensing regulator and relief valve. The manifold (system) pressure switch governs the operation of the air compressor. When the manifold pressure drops below 2,750 p.s.i., the pressure-sensing switch closes, energizing the separator's moisture dump valve and the hydraulic selector valve which activates the air compressor. When the manifold pressure builds up to 3,150 p.s.i., the pressure-sensing switch opens, de-energizing the hydraulic selector valve to deactivate the air compressor and dump valve, thus venting overboard any moisture accumulated in the separator.

The safety fitting, installed at the inlet port of the moisture separator, protects the separator from internal explosions caused by hot carbon particles or flames that may be emitted from the air compressor.

A chemical drier further reduces the moisture content of the air emerging from the moisture separator.

A pressure transmitter senses and electrically transmits a signal to the pneumatic pressure indicator located in the cockpit. The indicating system is an "autosyn" type that functions exactly like the hydraulic indicating systems.

An air-charge valve provides the entire pneumatic system with a single external ground servicing point. An air pressure gage, located near the air-charge valve, is used in servicing the pneumatic

system. This gage indicates the manifold pressure.

An air filter (10-micron element) in the ground air-charge line prevents the entry of particle impurities into the system from the ground servicing source.

The high-pressure air exiting from the fourth stage of the air compressor is directed through a bleed valve (controlled by an oil pressure tap on the pressure side of the oil pump) to the high-pressure air outlet. The oil pressure applied to the piston of the bleed valve maintains the valve piston in the "closed" position. When the oil pressure drops (due either to restriction of oil flow or to stopping of the compressor), the spring within the bleed valve re-positions the bleed valve piston, thereby connecting the inlet port and the drain port of the valve. This action unloads the pressure from the compressor and purges the line of moisture.

The air filter through which the ground-charge air passes is located immediately upstream of the air-charge valve. Its purpose is to prevent the entry of particle impurities into the system from the ground servicing source. The filter assembly is made up of three basic components—body, element, and bowl.

The pneumatic system air compressor inlet air is filtered through a high-temperature filter. Its purpose is to prevent particles of foreign matter from entering the compressor's absolute pressure regulator, thereby causing it to malfunction. The filter is an in-line, full-flow type (with integral relief valve) housed in a cylindrical body.

The moisture separator is the pneumatic power system's pressure-sensing regulator and relief valve, and is capable of removing up to 95% of the moisture from the air compressor discharge line. The automatically operated, condensation dump valve purges the separator's oil/moisture chamber by means of a blast of air (3,000 p.s.i.) each time the compressor shuts down. The separator assembly is made up of several basic components, each of which performs a specific function.

Components

The pressure switch controls system pressurization by sensing the system pressure between the check valve and the relief valve. It electrically energizes the air compressor solenoid-operated selector valve when the system pressure drops below 2,750 p.s.i., and de-energizes the selector valve when the system pressure reaches 3,100 p.s.i.

The condensation dump valve solenoid is energized and de-energized by the pressure switch.

When energized, it prevents the air compressor from dumping air overboard; when de-energized, it completely purges the separator's reservoir and lines up to the air compressor.

The filter protects the dump valve port from becoming clogged and thus ensures proper sealing of the passage between the reservoir and the dump port.

The check valve protects the system against pressure loss during the dumping cycle and prevents backflow through the separator to the air compressor during the relief condition.

The relief valve protects the system against over-pressurization (thermal expansion). The relief valve opens when the system pressure reaches 3,750 p.s.i. and re-seats at 3,250 p.s.i.

The thermostatically controlled wraparound-blanket type heating element prevents freezing of the moisture within the reservoir due to low-temperature atmospheric conditions. The thermostat closes at 40° F. and opens at 60° F.

Pneumatic Power System Maintenance

Maintenance of the pneumatic power system consists of servicing, troubleshooting, removal and installation of components, and operational testing.

The air compressor's lubricating oil level should be checked daily in accordance with the applicable

manufacturer's instructions. The oil level is indicated by means of a sight gage or dipstick. When re-filling the compressor oil tank, the oil (type specified in the applicable instructions manual) is added until the specified level. After the oil is added, ensure that the filler plug is torqued and safety wire is properly installed.

The pneumatic system should be purged periodically to remove the contamination, moisture, or oil from the components and lines. Purging the system is accomplished by pressurizing it and removing the plumbing from various components throughout the system. Removal of the pressurized lines will cause a high rate of airflow through the system causing foreign matter to be exhausted from the system. If an excessive amount of foreign matter, particularly oil, is exhausted from any one system, the lines and components should be removed and cleaned or replaced.

Upon completion of pneumatic system purging and after re-connecting all the system components, the system air bottles should be drained to exhaust any moisture or impurities which may have accumulated there.

After draining the air bottles, service the system with nitrogen or clean, dry compressed air. The system should then be given a thorough operational check and an inspection for leaks and security.